Water Management and Justice in the Borderlands:

Perspectives from and Analysis of the Santa Cruz River Basin

by

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ABSTRACT

The Santa Cruz River Basin shared by Northern Sonora and Southern Arizona is one example of transboundary water resources in the borderlands region that accurately portrays the complexities of binational management of common pool resources, such as water. Industrialization fueled by trade liberalization has resulted in migration to and urbanization along the border, which have created human rights issues with the lack of water and sanitation, groundwater overdraft of the shared aquifers, and contamination of these scarce resources. Effluent from wastewater treatment plants continues to play increasingly important roles in the region, the use of which has been a source of tension between the two countries. Contributing to these tensions are the strains on binational relations created by border militarization and SB 1070. A shift in water management strategies to increase pubic participation within decision-making, increase the flexibility of the water systems, and increase cross-border collaboration is needed to ensure human and ecological sustainability in the Santa Cruz River Basin. By incorporating direct communication and local capacity as per common pool resource theory, recognizing the connections and implications of management actions through socio-ecological systems understanding, and promoting the organic drivers of change through ecologies of agents, just and vigorous futures can be envisioned and advanced.

Keywords: Santa Cruz River, Ambos Nogales, common pool resource, transboundary water resources, binational management

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ACRONYMS

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
BECC	Border Environmental Cooperation Commission
BIP	Border Industrialization Program
CEA	Comisión Estatal del Agua
CILA	Comisión Internacional de Limites y Aguas
CPR	Common Pool Resource
CONAGUA	Comisión Nacional del Agua
EPA	Environmental Protection Agency
GCPD	Gallons Per Capita Per Day
IBWC	International Boundary and Water Commission
IOI	International Outfall Interceptor
LAWTP	Los Alisos Wastewater Treatment Plant
MGD	Million Gallons Per Day
NAFTA	North American Free Trade Agreement
NIWTP	Nogales International Wastewater Treatment Plant
NGO	Non-Governmental Organization
NPDES	National Pollution Discharge Elimination System Standards
NPO	Nonprofit Oganization
OOMAPAS	Organismo Operador de Agua Potable, Alcantarillado, y Saneamiento
TAAP	Transboundary Aquifer Assessment Program
UN	United Nations
USGS	United States Geological Survey

INTRODUCTION

Water is a fundamental requirement of life. All physical processes on the earth, whether they are geological or biological, rely upon this unique polar covalent molecule. Like all other creatures on the planet, humans too are reliant on water for their daily needs. All the water that has been and ever will be on the earth is roughly equivalent to 326 million trillion gallons of water. This incomprehensibly large number, however, quickly dwindles when we acknowledge that of this global total only 2.5% is freshwater, and of that freshwater, only 1% is available and accessible for human use (USGS, 1984). Increasing pressures from population growth, rapid urbanization, and climate change continue to put stress on this vital resource. The potential for scarcity of freshwater is compounded by competing claims/interests and conflicting management strategies for water resources that stretch across international lines. According to Wolf, Stahl, and Macomber (2003), there are 263 watersheds that cross political boundaries of nations covering a total of 45.3% of the land surface on earth and accounting for approximately 60% of global river flows.

The 1848 Treaty of Guadalupe Hidalgo and the 1854 Gadsden Purchase established the international border between the United States and Mexico, as we know it today (Ingram, Laney, and Gillilan, 1995). These political boundaries, however, did not follow natural watershed boundaries of the region, and as a result the United States and Mexico share water resources in the forms of rivers, streams, lakes, and aquifers. One specific case of transboundary water is within the Santa Cruz River Basin located in southern Arizona and northern Sonora.

The border community of Ambos Nogales is one of the largest urban centers within this binational river basin. Ambos Nogales, which means “both” Nogales in Spanish, comprises the twin border towns of Nogales, Sonora in Mexico and Nogales, Arizona in the United States.

With historic and present realities of water quantity and quality issues and tensions over the use of the resources, this border community and the Santa Cruz River Basin provide an excellent case study for the social, political, legal, economic, and environmental issues that are layered into water use and water management and the implications these have for human and ecological sustainability. As argued in this paper, a shift in water management strategies to increase pubic participation within decision-making, increase the flexibility of the water systems, and increase cross-border collaboration is needed to ensure human and ecological sustainability in the Santa Cruz River Basin.

This paper will examine the most salient management issues facing the river basin and analyze approaches to binational water management and the resolution of conflicts. The author will answer the following research questions: what are the most salient water management issues of the Santa Cruz River Basin both past and present and how do they differ on either side of the border; are the water systems sufficiently flexible to address water scarcity; and what have been the approaches to binational water management and the resolution of conflict and what has contributed to their successes and failures? A statement of the issues will be presented that provides in-depth description of the ecology/hydrology of the region and its historical context including trade and development policies, growth and infrastructure limits, binational attempts to solve problems, and brewing conflicts. The author's research will then be introduced with its grounding in theory and methodology, followed by an extensive discussion of the results, their significance, and potential solutions for this region of the borderlands.

A STATEMENT OF THE ISSUES

ECOLOGY, HYDROLOGY, AND MODERN HISTORY OF THE REGION

The Santa Cruz River is one of the most unique and historically biodiverse riverine systems in the U.S. Southwest and Mexican Northwest. It is a river that has captured the attention of generations of people from indigenous tribes such as the Pima and Tohono O'odham to Spanish soldiers and from Mexican *campesinos* to Anglo settlers. The riparian vegetation corridor following the Santa Cruz River cuts through the semi-arid, scrub ecology of the Sonoran Desert like a lush, green scar. Although the riparian corridor currently exhibits only a fraction of its previous grandeur, stepping inside transports one into a different world, one filled with towering cottonwood and willow trees, the cries of Mexican gray hawks, and a perceptible drop in ambient temperature. It has been described as "Eden" by those who hike the historic Anza Trail, portions of which follow the Santa Cruz River.[1] Even those who don't venture close can appreciate the beauty from afar, and as one Nogales, Arizona resident remarked, 'my favorite thing about the drive from Nogales to [Tucson] is seeing the soothing, green vegetation following the river.'[2]

[1] Anonymous, private citizen. Interview with author. March 29th, 2014, Tubac, AZ.
[2] Anonymous, private citizen. Interview with author. March 28th, 2014, Tucson, AZ.

Figure 1: Aerial view of the Santa Cruz River near Rio Rico, AZ (WRRC, 2013)

Figure 2: Inside the Santa Cruz riparian corridor (Photo from author)

The river's current name is borrowed from the Santa Cruz settlement established by Spanish soldiers in the 1700s in the San Rafael Valley southeast of present day Patagonia, Arizona. The headwaters of the Santa Cruz River drain from high elevation oak woodlands on the eastern slope of the Patagonia Mountains, from the southern slope of the Canelo Hills, and from the western slope of the Huachuca Mountain range near Sierra Vista, Arizona. The river flows south through the grasslands of the San Rafael Valley down to the U.S.-Mexico border where it crosses into Sonora two miles east of Lochiel, Arizona. Up until this point, the basin encompasses 82 square miles of Southern Arizona. Once in Sonora, the Santa Cruz River follows the topography of the region flowing south to the town of San Lázaro, Sonora from which it begins to head west and finally curves back northward where it crosses the border a second time reentering Arizona six miles east of Ambos Nogales. During its thirty-five mile loop into Sonora, the river basin encompasses a total of 348 square miles of land south of the border (Webb *et al*., 2014). The Santa Cruz River continues northward past Tucson eventually reaching its terminus south of Phoenix at its confluence with the Gila River, a tributary of the lower Colorado River (Logan, 2002). In its totality the Santa Cruz River Basin comprises 8,581 square miles of Southern Arizona and Northern Sonora. Especially in its lower reaches, however, the Santa Cruz River is and has been characterized by a dry streambed rather than a flowing waterway. As Webb *et al*. (2014) elaborated, "This river seldom flowed continuously from headwater to terminus and was—and still is—better defined by subsurface water than by surface flow" (p. 166).

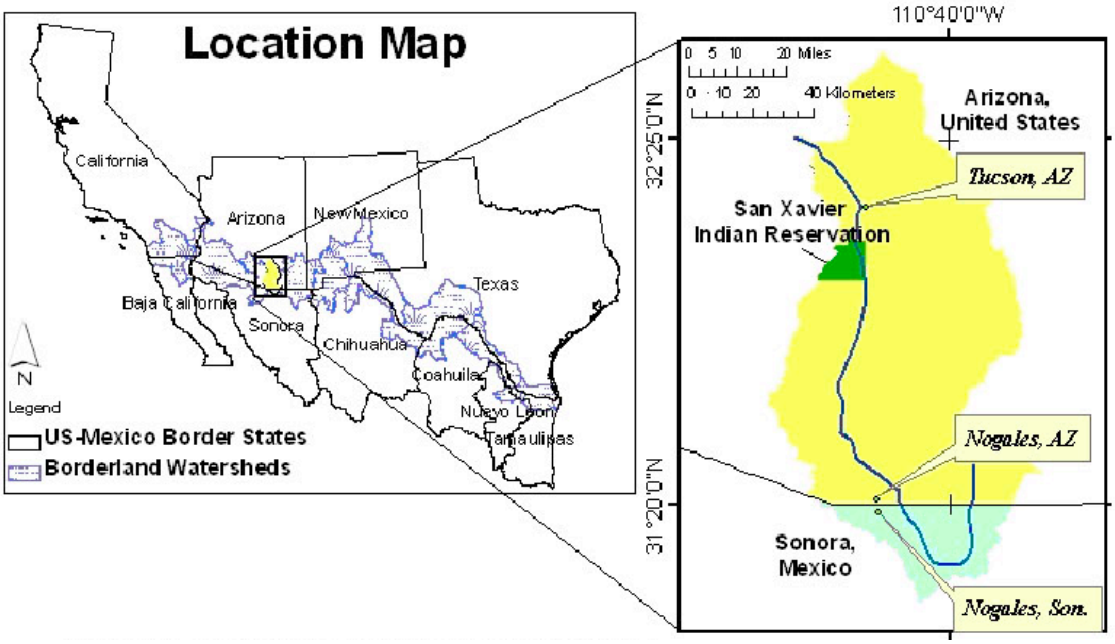

Figure 3: Santa Cruz River Basin (USGS, 2014)

The river basin aquifer and the subsequent microbasins that follow the Santa Cruz River are formed from highly permeable, young alluvial deposits (Logan, 2002). These shallow aquifers run approximately one mile wide and approximately 100 feet deep and are highly responsive to climatic changes and to anthropocentric uses (Ingram, Laney, and Gillilan, 1995). As a result, the shallow and highly permeable Santa Cruz River Basin is a "flashy" system with limited storage capacity, which means its water resources can be depleted very quickly depending on climate and groundwater pumping. These characteristics are important considering that water scarcity is a serious concern in the upper Santa Cruz River Basin, a concern that is elevated by unsustainable use of the groundwater.

The incipient communities of Ambos Nogales were erected directly above portions of the river's aquifer, and in the beginning years shallow, hand dug wells were the original and only supply of fresh water for the people. Things changed at the turn of the century. In 1896

groundwater pumping officially began taking place in the Ambos Nogales region of the Santa Cruz River Basin (Ingram, Laney, and Gillilan, 1995). Well fields were erected, and large-scale pumping efforts began. By the 1930s the upper Santa Cruz River was no longer a perennial river system as it failed to flow continuously above ground due to extensive groundwater pumping that had lowered the water table (Logan, 2002). The biodiverse riparian habitat including the Great Mesquite Forest that followed the Santa Cruz River began to fade away. The 1970s marked a tipping point in which groundwater levels dropped below the roots of the large growth riparian species resulting in large-scale die off of vegetation. According to Web *et al*. (2014), "nowhere in the Southwest [U.S.] has water development been more detrimental to riparian ecosystems and avifauna than along the Santa Cruz River" (p. 174). No longer flowing as a natural river, due to the groundwater pumping described above, river flow is dominated by effluent from wastewater treatment plants.

The modern cities of Ambos Nogales are situated in the floodplain of the Santa Cruz River within the semi-arid Sonoran Desert. The community sprang up in the late 1800s as railroad towns following the arrival of the railroad to the Tucson Basin in 1880 and the subsequent connection of the Arizona railroad to the Sonoran Railway through the Nogales Valley in 1882. At this time, approximately 800 residents occupied the collective community of Ambos Nogales (Logan, 2002). The region's economy was fueled by the railroad and the opportunities it brought such as cattle ranching and mining of the area's rich metal deposits, primarily copper. The area became a supply center for ranchers and miners, and in 1930 the population of Ambos Nogales had grown to about 20,000 with over 15,000 residents living on the Mexican side (Ingram, Laney, and Gillilan, 1995). However, a series of events eroded the economic base of the region. The resurgence of revolutionary violence with the Six Weeks'

Revolution in 1929 in Mexico disrupted the flow of goods through the region, the U.S. Tariff Act of 1930 reduced trade from Sonora to Arizona, and the effects of the Great Depression in the U.S. and Mexico eroded the economy of the cities. As copper prices fell, thousands of miners and laborers were laid off. The end of the Depression saw economy of Ambos Nogales on the rise again, this time also incorporating large-scale cattle and winter vegetable exports into their economic portfolio, and by 1950 the city's population had surpassed 30,000 people, once again with the majority (approximately 26,000) living in Nogales, Sonora (Ingram, Laney, and Gillilan, 1995).

RECENT TRADE AND DEVELOPMENT POLICIES

Border industry has been and continues to be the largest factor affecting population growth in this region, which has important implications for water use and availability. In 1965 the Mexican government launched the Border Industrialization Program (BIP) in an attempt to create jobs, stimulate the economy in the north, and promote continued growth. BIP allowed foreign owned companies to own and operate manufacturing plants in Mexico and became part of the larger pattern of denationalization and deregulation seen along the border. In general, these factories imported materials and parts, used Mexican labor to assemble the goods, and then exported these items to large commercial markets. This production occured at low cost due to incentives such as Mexican taxes only being applied to "value added" by Mexican labor as opposed to the value of the entire product (Lara-Valencia *et al*., 2009). These foreign owned manufacturing plants are known as *maquiladoras*, which translates to "miller's portion" in Spanish referring to the share of flour withheld as payment for milling services. In 1967

Nogales, Sonora's first *maquiladora* went into operation (Ingram, Laney, and Gillilan, 1995; Lara-Valencia *et al*., 2009).

Nogales, Sonora drew a large number of *maquiladoras* and corresponding laborers, increasing its official population to over 68,000 in 1980 and over 107,000 by 1990 (Ingram, Laney, and Gillilan, 1995). Trade liberalization policies such as Mexico's 1989 *Maquiladora* Decree dramatically aided in border industrialization. This decree decreased restrictions to foreign companies, such as the elimination of time limits on *maquiladora* licenses. These policies served as precursors to the ratification of the North American Free Trade Agreement (NAFTA) between Canada, the United States, and Mexico in 1994 (Kagan, 2005).

This industrialization was a part of a vicious cycle playing out in Mexico. Agricultural subsidies in the United States and Western Europe created and continue to create a structural advantage for large-scale food operations in the Global North. These subsidies combined with trade liberalization policies, most notably NAFTA, as well as market reforms pushed by the World Bank and International Monetary Fund, have led to food and economic insecurity in the Global South. Transnational agribusiness food exported to (or, as some critics charged, "dumped" in) the Global South artificially depressed local food prices, which impoverished small farmers throughout Latin America including Mexico and led to mass rural to urban migrations (Holt-Gimenez, 2011; Gonzalez, 2010; Wittman, 2009). In Mexico, these *campesinos* migrated northward to urban centers, drawn by the allure of manufacturing jobs along the border and to the hope of a better life in the United States (Wise and Breña, 2006).

GROWTH AND INFRASTRUCTURE LIMITS

After NAFTA was enacted, the population of Ambos Nogales exploded as more industries moved to this border town to take advantage of liberalized trade. As of 2006, there were ninety-five active factories in Nogales, Sonora (Prichard and Scott, 2013). Over the decades, Ambos Nogales saw tremendous population growth and corresponding urbanization, in part as a result of trade liberalization policies (Norman *et al*., 2012; Mumme, 2008). However, as Figure 4 clearly shows, this growth was not evenly distributed across the border. The population growth of Ambos Nogales is relatively stable north of the border and almost exponential south of the border. Lacking the industrialization push described previously, the Arizonan side of the border has had relatively little population growth and has seen some stagnation in current times. To this day it remains a sleepy community. The official population of Nogales, Arizona decreased slightly from 20,878 to 20,837 during the 2000 to 2010 decade. The official population of Nogales, Sonora, on the other hand, increased from 159,787 in 2000 to 220,292 in 2010 and is not predicted to stabilize until 2060 (Scott and Buechler, 2013). Given the transient nature of many of the community's inhabitants and the census difficulties associated with squatter communities, official counts could significantly underrepresent the total population, which has been estimated as high as 450,000.[3]

[3] Anonymous, U.S. IBWC official. Interview with author. October 2nd, 2014, Rio Rico, AZ.

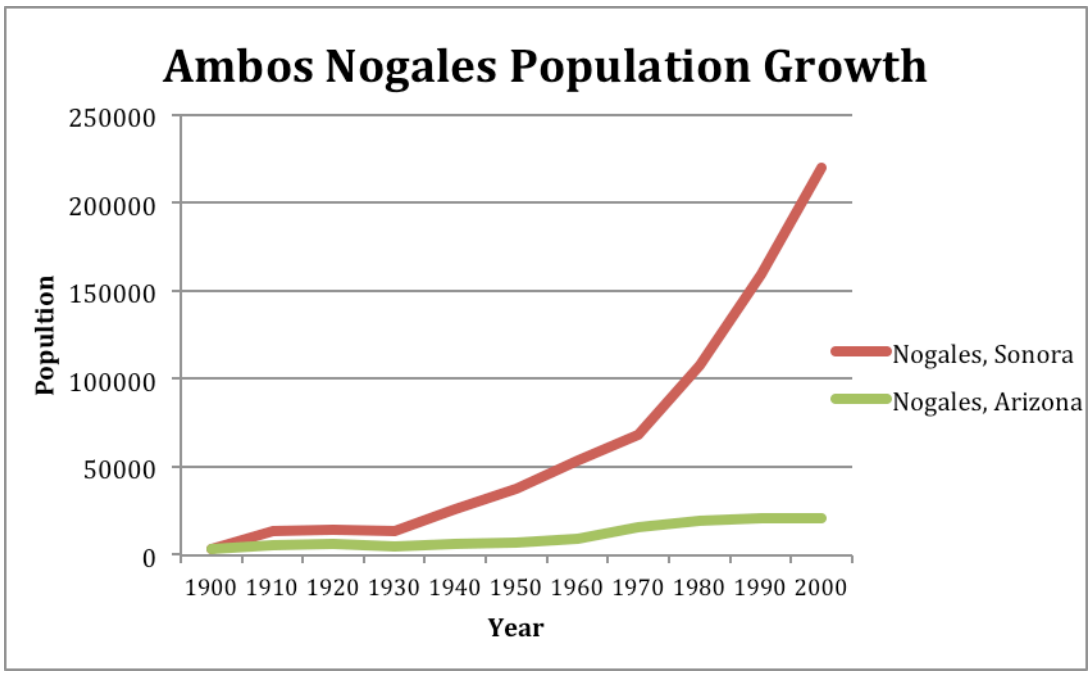

Figure 4: Nogales, Sonora and Nogales, Arizona populations (adapted from Prichard and Scott, 2013)

Unable to accommodate such large influxes of people within the city proper, peri-urban communities have arisen in the hillsides surrounding the city of Nogales, Sonora. These communities are sometimes denoted as "new towns", "shanty towns", or "squatter communities" and are known colloquially as *colonias marginadas* (hereafter referred to as simply *colonias*). The *colonias* are important because this is where several issues of human rights and sustainability intersect including the right to water and sanitation and riparian habitat loss and water resource contamination. Human rights are the conditions and freedoms that all individuals are entitled to by virtue of their being. In an effort to promote and protect universal human rights, various mechanisms such as resolutions and treaties have been established by the United

Nations (UN). In 2010, the UN officially recognized access to drinking water and sanitation as human rights (UN, 2010).

In Nogales, Sonora, approximately 85% of the population have access to potable water, ranging from full twenty-four hour availability to as low as three hours per day. By and large, the *colonias* do not have access to municipal infrastructure and comprise nearly the full 15% of the population that does not have access to potable water or sewage (Norman *et al*., 2012; Scott and Buechler, 2013). The lack of safe drinking water and sanitation services threatens the health and dignity of human life, and thus is a human rights issue. Complicating matters further, many of the *colonias* have been constructed on impervious rock formations in the hillside areas, making the possibility for underground, piped connections very difficult. Individuals and households in these areas are forced to rely on carrying water from community wells, purchasing water from stores, or most commonly by purchasing water from water trucks known as *pipas*. This water is then stored in large containers, such as 55-gallon metal and plastic drums (Ingram *et al*., 1995; Norman *et al*., 2012). *Pipas* are operated both by the local utility, Organismo Operador de Agua Potable, Alcantarillado, y Saneamiento (OOMAPAS) and by private owners. Water from *pipas* is not only more expensive than a traditional municipal connection, but their deliveries are also unreliable and water contamination can be a concern. This is especially true of privately owned *pipas*, whose water sources and water transportation protocol do not have to meet the same quality standards that OOMAPAS is supposed to follow (Norman *et al*., 2012).

The lack of sewage infrastructure in the *colonias* also poses serious issues for these communities. Open defecation and open pit latrines are the most common means of disposing of human fecal matter, both of which pose serious problems for health as they readily contaminate water sources. With heavy rainfall (especially prevalent during the summer monsoon), fecal

contamination spreads, as fugitive wastewater enters washes and is carried throughout the city. According to a recent study by Norman *et al*. (2012), approximately 80% of the *colonia* households surveyed had *E. Coli* levels in their drinking water above health standards in the summer, and approximately 50% in the winter with a subsequent rate of diarrhea in individuals averaging 50%.

Nogales, Arizona provides a different story. With political and economic support from the national level and without the infrastructural burden of the border industry at the state and city level, Nogales, Arizona's relatively consistent population (approximately one tenth that of its southern neighbor) has enjoyed the full benefit of municipal services of a wealthy nation that has invested heavily in infrastructure. Water is continuously supplied to 100% of the city at a constant pressure, and is of high quality (Ingram, Milich, and Varady, 1994). There are quality concerns in some of the well fields, but these are minor compared to water quality issues in Sonora. Also, by as early as 1946 nearly 100% of the city had piped sewer connections. This reliable, high standard of potable water and sanitation services has shifted the focus of the public away from issues of household provision (as one would find in Sonora) to those of environmental impact and water quality (Ingram, Laney, and Gillilan, 1995). This affords residents of Nogales, Arizona the privilege of focusing their concern on the waters of the Santa Cruz River and its associated wildlife.

BINATIONAL ATTEMPTS TO SOLVE PROBLEMS

Being an international river, the Santa Cruz is subjected to the jurisdiction of international commissions and organizations. In 1889 due to difficulties with the use of the Rio

Grande River in New Mexico and Texas, the United States and Mexico held a convention that established the U.S. International Boundary and Water Commission (IBWC) and Mexican equivalent the Comisión Internacional de Limites y Aguas (CILA), which have the authority to manage and regulate transboundary water. IBWC/CILA draft joint resolutions regarding their boundaries and shared waters, which when approved by their respective federal governments, create binding international agreements between the two nations. The 1944 Treaty for the Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande allocated the water resources between the two countries, and later in 1983, the La Paz Agreement between the U.S. and Mexico established guidelines for addressing environmental issues in the borderlands, specifically focusing on water quality and pollution. Up until 1989, however, only international surface waters had been addressed by the United States and Mexico. In this year the countries approved the Bellagio Draft Treaty, which provided a model for joint research and cooperative management of transboundary aquifers (O'Leary, 2003).

More recently in 1993, governments of the U.S. and Mexico established the Border Environment Cooperation Commission (BECC) as a side agreement to the North American Free Trade Agreement (NAFTA) to help protect the environment and human health in the border region (Schoik, 2003). Finally, in 2006, President George Bush signed and enacted the U.S.-Mexico Transboundary Aquifer Assessment Act to address the need for comprehensive evaluation of the borderlands aquifers. Water research centers within the United States Geological Survey (USGS) and the University of Arizona have partnered with stakeholders from Mexico to conduct studies sanctioned by the act that focus on the four priority transboundary aquifers, of which the Santa Cruz is one. Its legislation, however, is determined by and only applies to the U.S. portion of the basin (Varady, Castelo, and Eden, 2012). These measures

described above provide the official platform and vehicle for binational management of the Santa Cruz River Basin. Their progression over the years demonstrates a realization of the different management needs of the region and embodies a level of fragmentation that complicates the governance processes.

The river is also governed at the state level on the U.S. side. Following the passing of the Arizona Groundwater Management Act in 1980, restrictions on groundwater pumping were implemented in critical groundwater areas in south central Arizona. In 1989, the Arizona Department of Water Resources (ADWR) actually cited and fined the City of Nogales, Arizona for overdraft of the aquifer and for exceeding per capita pumping limits (the fee was later waived) (Ingram, Laney, and Gillilan, 1995). In 1994, the state of Arizona officially designated the U.S. portion of the Upper Santa Cruz River Basin as an Active Management Area (AMA), meaning that all significant withdrawals of groundwater are regulated under a permitting system established by Arizona statutory law under title 45 (Brown *et al*., 2003). The two goals of the Santa Cruz Active Management Area are to maintain safe yield of groundwater in which annual withdrawals are equivalent to annual recharge and to prevent water tables from experiencing long-term declines.

The formal powers established to govern the river and the associated water have attempted to address some of the issues that have faced and continue to face this shared water resource. The population boom that Nogales, Sonora experienced throughout the 1900s left the city's municipal infrastructure unable to keep up with the continuing influx of people. As a result, providing potable water to the Sonoran city became a challenge, as did the proper collection and treatment of sewage. Untreated wastewater overflows and raw sewage runoff crossing the border from Nogales, Sonora prompted the U.S. Congress and the IBWC to

authorize the creation of an international treatment plant (Ingram, Laney, and Gillilan, 1995). To date, the largest binational attempt to solve issues of wastewater treatment capacity was the creation of this international treatment program. The first international treatment plant was located just north of the border in downtown Nogales, Arizona. It became fully operational in 1951 and released its treated effluent into the Santa Cruz River, which helped to augment surface flows (Logan, 2002).

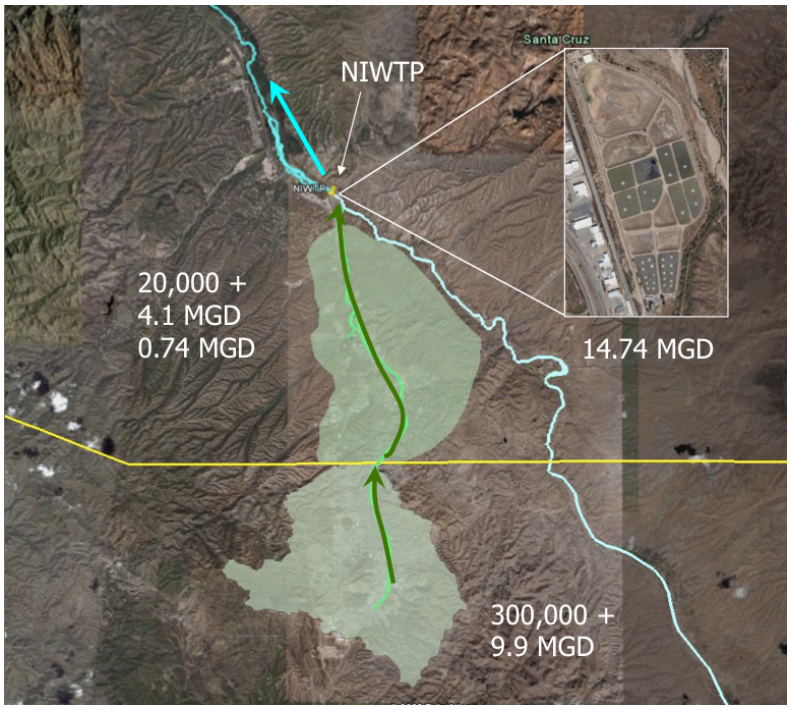

Figure 5: NIWTP sewage flows portrayed in green (Huth, 2009)

However, by 1958 this treatment plant was already exceeding capacity and was overwhelmed by the population growth of Ambos Nogales. Issues with sewage overflows heading north became a problem once more. To address this, the plant was upgraded and relocated ten miles north of the border to Rio Rico, Arizona. This plant called the Nogales International Wastewater Treatment Plant (NIWTP) was completed in 1972. This plant has a

14.7 million gallons per day (MGD) capacity, and under the IBWC treaty, Mexico pays roughly $300,000 a year to send 9.9 MGD of sewage north across the border to be treated at the NIWTP, as shown in Figure 6 (Varady, Castelo, and Eden, 2012; Brown *et al*., 2003). On average, Mexico has been exceeding its IBWC treaty allotment of 9.9 MGD by 126%, which has resulted in the incurring of extra fees (NADB, 2012). From 2008-2012 sewage flows from Nogales, Sonora averaged 11.48 MGD while flows from Nogales, Arizona averaged 3.94 MGD. With the NIWTP being the only legitimate outlet for the extra sewage, U.S. IBWC regional director John Light stated that the agency would rather treat the extra flows than have them be discharged as renegade flows into streams, which would ultimately flow north across the border. However, this does put extra pressure on U.S. infrastructure.[4]

Historically, the NIWTP consistently failed to meet National Pollution Discharge Elimination System Standards (NPDES) (Brown *et al*., 2003). The effluent being released into the Santa Cruz River downstream from the plant in Rio Rico violated water quality standards and limits contained in its NPDES permit, and nearby residents reported it having a strong ammonia odor.[5] This prompted the Sierra Club to file a lawsuit against the Environmental Protection Agency (EPA) regarding the quality of the effluent and helped bring greater public attention to the issue. A compliance order was implemented, which contributed to the NIWTP receiving a $64 million upgrade funded almost in full by the EPA in 2009 (Norman *et al*., 2012).

[4] Light, John, U.S. IBWC regional director. Interview with author. October 2nd, 2014, Rio Rico, AZ.
[5] Sass, Sherry, current treasurer and former founder of Friends of the Santa Cruz River. Interview with author. March 29th, 2014, Tubac, AZ.

Figure 6: NIWTP effluent discharging into the Santa Cruz River (Photo from author)

Effluent (now of a high quality due to the upgrade) seen in figure 6 continues to dominate the Santa Cruz River, and without which the northbound river would be completely dry. Riparian habitats and recharge of the shallow aquifers downstream from Rio Rico, Arizona are dependent upon the continued flow of effluent from the NIWTP, which is now clean, clear, odor free, and within the NPDES standards. Since the plant upgrade in 2009, fish, such as the Gila topminnow and Longfin Dace, have appeared in the Santa Cruz River after having vanished decades prior (Varady, Castelo, and Eden, 2012). The river now supports a variety of threatened and endangered species including the Pima pineapple cactus, lesser long-nosed bat, Yellow-bellied cuckoo, and Southwestern willow flycatcher among others. Reports have also documented the presence of large, predatory cats such as the jaguar and ocelot within the area.

One curious phenomenon that occurred since the upgrade to the NIWTP was the shortening of the flowing river, which during previous years had been reaching farther and farther north despite relatively constant effluent outflows. This was determined to be a result of

the nutrient rich, poor quality effluent creating a bio-film layer in the streambed that significantly reduced infiltration. The higher quality effluent from the upgraded plant has reduced the sealing of the streambed and has promoted greater infiltration into the ground. The current river, though, despite the large inputs of effluent, still does not flow continuously, as seen in figure 7. This is due to diurnal variations in wastewater entering the NIWTP. Use of municipal water is not constant but has peaks in the morning and evening, which translate into fluctuations in the amount of wastewater received and effluent released during a given time period. For the Santa Cruz River, whose flows are entirely dependent upon NIWTP effluent, the temporary disappearance of the river in its reaches near Tumacácori, Arizona presents significant barriers to the widespread reestablishment of fish species.[6]

Figure 7: Before and after showing diurnal variations over a 2-hour period of the Santa Cruz River near Tumacácori, Arizona (Photos from author)

Often overlooked by scholars and conservationists, there is a peculiar, contemporary relationship between groundwater pumping in Ambos Nogales and the riparian habitat following

[6] Sass, Sherry, current treasurer and former founder of Friends of the Santa Cruz River. Interview with author. March 29th, 2014, Tubac, AZ.

the river north of Rio Rico, Arizona. As stated before, the riparian habitat along the Santa Cruz River was historically dependent upon high water tables, which were subsequently *reduced* by groundwater pumping, whereas the current riparian habitat is dependent upon *continued* groundwater pumping in Ambos Nogales. At first glance these statements seem contradictory. However, the current, dominant riparian habitat is artificial and is entirely dependent on effluent from the NIWTP. Increased groundwater pumping in Ambos Nogales increases the amount of wastewater delivered to the NIWTP, which increases the amount of effluent supporting the habitat. Therefore, this provides an interesting case in which water conservation efforts would actually negatively impact the riparian habitat. It serves as an important reminder that although the present riparian habitat is biodiverse, it is artificial and cannot be relied upon for long-term, environmental conservation and preservation efforts.

BREWING CONFLICTS

Present realities of water scarcity have led to some brewing conflicts within the Santa Cruz River Basin. Currently the water use in Nogales, Arizona is approximately 200 gallons per capita per day (GPCD) (Frisvold and Osgood, 2011). It has a relatively high GPCD when compared to the rest of the state and nation due in part to non-residential water demand associated with daily border crossings from Sonora (ADWR, 2014b). Nogales, Arizona draws its water from well fields within the basin to the northeast of the city (Varady, Castelo, and Eden, 2012). South of the border, however, water use is 48 GPCD (less than a quarter of water usage to the north), and it draws from a variety of sources (Scott and Buechler, 2013). Approximately half of Nogales, Sonora's potable water supply comes from the Santa Cruz River aquifer from two well fields (Scott *et al.,* 2012). However, as mentioned earlier, increasing demand and

declining productivity (as a result of greater lifting from deepening water tables) from the Santa Cruz River watershed led Mexico to develop well fields in the Los Alisos Basin of the Magdalena watershed. The other half of Nogales, Sonora's water supply is pumped from this basin near the town of Cibuta, Sonora, which is hydrologically separate from the Santa Cruz River (Varady, Castelo, and Eden, 2012). As a former director of the Santa Cruz AMA stated, "Interbasin transfers are a very typical water management response in both the southwestern United States and northwestern Mexico [because] where there's a need for economic development and for population growth the water resources are found from somewhere, always."[7] This contemporary model relies almost exclusively on anthropocentric metrics and values and generates environmental and interspecies concerns.

These water transfers sometimes pose issues: "From the environmental perspective, any transfer of water from one watershed to another watershed… is a big *NO* in terms of energy consumption and in terms on allocation of water" said one Sonoran who was involved in watershed management.[8] Engineers from a private Sonoran irrigation company also noted that 'interbasin transfers disrupt the natural equilibrium', and as a result water should stay within the watershed.[9] However, facing very real water supply shortages amid continued population growth, the creation of new out-of-basin well fields is a relatively simple short-term solution. One need not look far for other prominent examples of water transfers. Tucson, Arizona located only 60 miles north of the U.S/Mexico border receives Colorado River water from the Central

[7] Anonymous, former director of SCAMA. Interview with Author. October 27th, 2014, Tucson, AZ.
[8] Anonymous, NPO watershed manager/researcher. Interview with author. October 22nd, 2014, Tucson, AZ.
[9] Anonymous, irrigation engineer. Interview with author. August 8th, 2014, Hermosillo, SO.

Arizona Project. This water travels 336 miles and is raised 2,400 feet to reach Tucson where it supplies about 26% of the city's water supply (ADWR, 2014a).

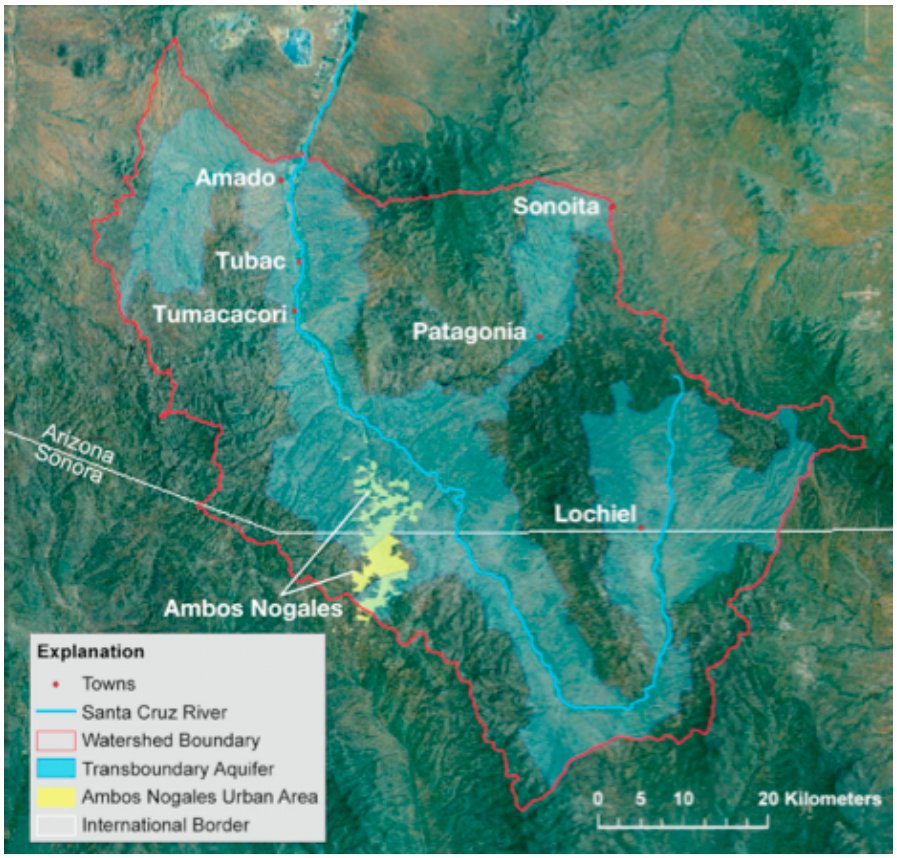

Figure 8: The upper Santa Cruz River and its associated aquifers (Scott *et al*., 2012)

The Santa Cruz AMA on the U.S. side of the border is currently at - and is maintaining - safe yield goals for the aquifer in which withdrawals equal recharge. Based upon 2011 water transfer data, though, the Sonoran Santa Cruz microbasins are facing a net loss of 8.8 million cubic meters annually (Prichard and Scott, 2013). This is significant because when withdrawals greatly exceed recharge, the water use poses potential future problems of availability and reliability. Unfortunately, Web *et al*. (2014) noted that "most of the groundwater lost to overdraft in the past 50 years accumulated during wetter times, particularly during Pleistocene

climates, [and] [i]t cannot be recharged to past levels under present-day climates and current or additional water demands" (p. 182). Quite simply, there is not enough water present in the basin to sustain the region's ecosystems and the urban centers in their present form. Also, due to the interbasin transfers of water into Nogales, Sonora, the potential for dewatering of aquifers is not localized to just the Santa Cruz River Basin. Prichard and Scott (2013) reported that since extensive groundwater pumping began in the Los Alisos Basin in 1996 (coinciding with the population spike in Nogales, Sonora) the water table there has dropped significantly, and the Los Alisos River, flowing through Cibuta, Sonora has disappeared. Many private wells in and near Cibuta no longer reach the water table due to the large pumping capacity of the deep municipal wells, and those that still reach water face increasing pumping costs (Prichard and Scott, 2013). With an eerily similar fate to that of the Santa Cruz River, farmers who depended upon the Los Alisos River are facing an uncertain future; a future that could include forced migration to urban centers such as Nogales, Sonora.

Representatives of OOMAPAS in Nogales, Sonora realize the implications of interbasin transfers stating that "[It] is not just nor fair that lots of water extracted from the Los Alisos Basin is poured into the Santa Cruz Basin." [10] However, their supply augmentation efforts endure as they continue to support a growing population with one OOMAPAS official stating that "…as the city grows, there will be a need for more well fields [in the Los Alisos Basin]." [11] These decisions come not without protest from community members living to the south of Nogales in the Magdalena watershed. In separate interviews, two U.S. water managers (one federal and one state) each described attending various water management meetings over the years in Nogales

[10] Anonymous, OOMAPAS representative. Interview with author. December 2nd, 2014, Nogales, SO.
[11] Anonymous, OOMAPAS employee. Interview with author. December 2nd, 2014. Nogales, SO.

and the nearby town of Magdalena and being surrounded by protesters from the Los Alisos area who were demanding that their water not be stolen.[12] [13] Water is on the people's mind, and they are willing to speak out against what they view as theft, in this case specifically referring to the city's transfer of water from the Los Alisos Basin. This demonstrates the willingness and the ability of some residents of Northern Sonora to organize around the topic of water availability, and this engagement indicates possible widespread interest and involvement in formal spaces for public participation. These examples can counter critiques of participatory decision-making that state the public is uninterested in governance. Powerful change can come from collective action, so it is important to look to examples such as these to promote and advocate for public dialogue space within management to incorporate lived experience into policy.

Also related to the growing problems of water scarcity are issues revolving around ownership and use of wastewater. What has often been traditionally dismissed as waste, effluent is now seen as an important resource within the Santa Cruz River Basin. Ownership and use of this effluent has generated tensions between the two states. Currently, approximately 1/3 of the sewage flow to the NIWTP is from Nogales, Arizona and the remaining 2/3 are from Nogales, Sonora. This Sonoran sewage is gravity fed to the plant through the International Outfall Interceptor (IOI) underground running parallel to Nogales Wash (Varady, Castelo, and Eden, 2012) (See Figure 9). It is important to note, though, that of the total amount of wastewater being treated at the plant and released into the Santa Cruz River, approximately 1/3 is from the Los Alisos Basin (an interbasin transfer). This is significant because this is "extra" water enters

[12] Anonymous, former ADEQ employee specializing in the U.S. Mexico border. Interview with Author. October 27th, 2014, Tucson, AZ.
[13] Anonymous, U.S. EPA water and wastewater specialist. Phone interview with author. October 29th, 2014.

this river system only through feats of human engineering. This is an extra benefit to riparian habitat and aquifer recharge north of the border, but it represents increasing groundwater mining south of the border and increasing conflicts among uses.

Much to the dismay of conservationist groups in Arizona such as Friends of the Santa Cruz River, the future of these riparian habitats is not legally protected. Under Resolution 11 of IBWC Minute 277, Mexico has the right to retain its wastewater and/or recapture its effluent (Brown *et al*., 2003). For decades, Mexico has been expressing its interest in treating and reusing its own wastewater as a means to help augment supply, which could correspond to a reduction in the amount of wastewater piped north across the border to the NIWTP, thus reducing the amount of effluent released into the Santa Cruz River. This is a topic that has split the residents of Arizona. According to one Arizona Department of Environmental Quality (ADEQ) employee, those who do not understand the important role effluent plays in the Santa Cruz AMA are not fond of the current treaty agreements that allow Nogales, Sonora to get their sewage treated in Arizona. He described this as sentiments of "dirty Mexicans with their dirty water," and that these real issues of people and the environment are often politicized and racialized.[14] On the other hand, there are many that want to incentivize Mexico's shipment of sewage north. These individuals are conservationists and environmentalists who see the Mexican effluent as an important asset to maintaining riparian habitat and to replenishing Arizona groundwater supplies. They state that negative perceptions of Mexican wastewater are due to a general lack of public awareness about the river.[15] [16] [17] John Light of the IBWC stated:

[14] Anonymous, ADEQ employee specializing in the U.S.- Mexico border region. Interview with author. March 27th, 2014, Tucson, AZ.
[15] Anonymous, ADEQ employee specializing in the U.S.-Mexico border region. Interview with author. March 27th, 2014, Tucson, AZ.

> "I'm always asked in public meetings why are we treating Mexico's waste? Well, first off it's a sanitation issue, and that's why the 1944 water treaty listed sanitation as one of the most important aspects. Second, is that we get that water… so there is a direct benefit to the United States for doing it." [18]

Some suggest that as water resources get more and more scarce, the United States should even consider paying Mexico to receive its sewage. [19] [20] [21] However, there are no guarantees that the Mexican wastewater will continue to flow north. Rumors circulated that Mexico might build a pipe from Rio Rico, Arizona to Nogales, Sonora to transport their treated effluent from the NIWTP back to their city, totally bypassing the Santa Cruz River. Officials from the IBWC dispelled these rumors stating that although legally possible, these attempts would never be economically feasible due to the cost of pumping the returning effluent up gradient. [22]

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[16] Anonymous, private citizen engaged in Santa Cruz River conservation efforts. Interview with author. March 28th, 2014, Tucson, AZ.
[17] Sass, Sherry, current treasurer and former founder of the Friends of the Santa Cruz River. Interview with Author. March 29th, 2014, Tubac, AZ.
[18] Light, John, regional director of the U.S. IBWC. Interview with author. October 2nd, 2014, Rio Rico, AZ.
[19] Anonymous, ADEQ employee specializing in the U.S.-Mexico border region. Interview with author. March 27th, 2014, Tucson, AZ.
[20] Anonymous, private citizen engaged in Santa Cruz River conservation efforts. Interview with author. March 28th, 2014, Tucson, AZ.
[21] Sass, Sherry, current treasurer and former founder of the Friends of the Santa Cruz River. Interview with Author. March 29th, 2014, Tubac, AZ.
[22] Anonymous, U.S. IBWC official. Interview with author. October 2nd, 2014, Rio Rico, AZ.

Figure 9: Wastewater shipment to LAWTP (Huth, 2009)

Recently however, Mexico did follow through on its desires to retain its wastewater through the construction and completion of the Los Alisos Wastewater Treatment Plant (LAWTP) in 2012, which is located south of Nogales, Sonora. This $20 million project was designed to address issues of excess sewage flowing to the NIWTP (and associated, incurred fees), accommodate increasing population growth, provide new sewage coverage to the Nogales region of Sonora, and recharge the Los Alisos Basin (Varady, Castelo, and Eden, 2012; Prichard and Scott, 2013). Cost-benefit analyses still favor Mexico's utilization of the NIWTP: the cost to Mexico for operation and management of this facility is relatively cheap as it is heavily subsidized by the U.S. IBWC, and the sheer quantities of wastewater necessitate this additional

capacity. Sewage is also gravity fed via the IOI to the NIWTP, whereas it must be pumped up gradient past the Los Alisos divide to enter the LAWTP (Figure 9), which uses significant amounts of energy and money.[23] The LAWTP will present both challenges and solutions for the region depending on one's perspective on ecosystems and equity.

RESEARCH QUESTIONS

Given the unique historic and contemporary context of binational water use and management in the Santa Cruz River Basin and potential future issues, this region makes a very interesting and pertinent study of transboundary water along US/Mexico borderlands. The second half of this paper will engage the themes addressed previously to analyze the approaches to binational water management and conflict resolution within the Santa Cruz River Basin to determine if the current systems are flexible enough to address water scarcity. The research questions are: Are the systems in place sufficiently flexible to address water scarcity? What have been the approaches to binational water management in the Santa Cruz River Basin? Why have these efforts succeeded or failed? As water continues to become more scarce in the Sonoran Desert, the answers to these questions will continue to become more crucial, as they address shortcomings and point toward more effective and meaningful actions for these shared water resources. The futures of Ambos Nogales and the Santa Cruz River depend upon addressing and solving the pressing issues related to binational water management in ways that address human rights, equity, and environmental sustainability.

[23] Anonymous, U.S. IBWC employee. Interview with Author. October 2nd, 2014, Rio Rico, AZ.

THEORETICAL FRAMEWORK

This paper's theoretical framework draws from common pool resource (CPR) theory established by Elinor Ostrom (1990) focusing on the efficacy of polycentric governance and utilizing a socio-ecological systems understanding of interactions between humans and the environment (Ostrom, 2009; Poteete, Janssen, and Ostrom, 2010). This paper also employs the concept of "ecology of agents" established by Peter Evans (2002) as a tool for evoking and directing positive change. These provide an effective framework because they are flexible and can encompass and adapt to the complexity inherent not only in water management in general but also water management across international boundaries. They speak not only to human needs but environmental needs as well, and unlike other theories and models they illustrate how these two realms are interconnected.

Ostrom (1990) defined a CPR as a "…naturally or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining the benefits from its use" (p. 30). Within CPRs, multiple appropriators can use and subtract from the resource simultaneously or sequentially and reduce its availability to other appropriators. Certain circumstances can lead to what Garrett Hardin (1968) famously described as "the tragedy of the commons" in which open access CPRs become over allocated, resulting in the degradation of the resource. This deals with what is known as the "free-rider problem" and "appropriation problem" in which everyone benefits from the resource yet not all contribute to it, thus resulting in very high marginal benefit and very low marginal cost for users (Poteete, Janssen, and Ostrom, 2010).

> "Therein is the tragedy. Each man is locked into a system that compels him to increase his [share] without limit- in a world that is limited. Ruin is the

> destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons." (Hardin, 1968, p. 1244)

The tragedy of the commons assumes that each appropriator or user acts out of self-interest, their decisions are made independently, and that there is no communication between individuals. This follows a game theoretic approach to decision making embodied by the Prisoner's Dilemma, which predicts equilibriums of noncooperation and therefore resource degradation (Dawes, 1974; Ostrom, Gardner, and Walker, 1994; Poteete, Janssen, and Ostrom, 2010). This means that users acting independently according to self-interest will behave in ways that are contrary to the best interests of the whole, thus leading to the exploitation and degradation of the CPR.

The concept of the tragedy of the commons has been used to inform other theories and to describe a variety of phenomena. It has been used to illustrate various issues of sustainability such as population growth and overpopulation, exploitative logging of forests, and collapses of fisheries to name a few (Baden and Noonan, 1998; Bowles, 2004). Proposed remedies for the tragedy of the commons often revolve around two themes: state (i.e. government) sanctions on the use of the resource and privatization of the resource with its use being governed by market forces (Ostrom, 1990; Poteete, Janssen, and Ostrom, 2010). Proponents of the tragedy of the commons often use its arguments to advocate for Lockean property rights over the resources stating that privatization is the most efficient and effective means for conservation (Smith, 1981). The tragedy of the commons is not without its critiques, however. Some assert that it has been used as propaganda for privatization movements, particularly those targeting indigenous and poor of the Global South (Jensen, 2007). Hardin's framework has also been used to promote the overlay of economic rationality onto the environment and other social/cultural systems and enforce or maintain structures of power (Appell, 1993). Others posit that the traditional

governing of the commons was quite effective, and that Hardin's framework failed to take into account local solution making (Dahlman, 1991).

As potential solutions to the tragedy of the commons, Ostrom critiqued formal controls stating, "…neither the state nor the market is uniformly successful in enabling individuals to sustain long-term, productive use of natural resource systems" and suggested that there are in fact effective alternatives utilized by communities of individuals (1990, p. 1). Her theory proposed that the commons need not always be a tragedy, and that individuals and communities can and do work together to properly manage CPRs. Keys to success rely on a variety of factors, and differ slightly depending on context; however, opportunities for communication, most importantly face-to-face communication, between appropriators dramatically increased the longevity and sustainable use of the resource (Ostrom, Gardner, and Walker, 1994; Poteete, Janssen, and Ostrom, 2010). Also, for CPRs that are a part of larger systems, a nested, or polycentric model of governance was important for the success of that commons (Ostrom, 1990; Ostrom, 2010). This model of governance coordinates institutional arrangements at multiple scales by promoting capacity and decision-making at the lowest level with resources from and accountability to higher-level structures (Garrick, Lane-Miller, and McCoy, 2011).

Water is an example of a CPR. It has definable resource units often measured as acre-feet or cubic meter per second, it has definable resource systems such as geologically delineated aquifers and basins, and one's use of the resource can limit another's use of the resource. However, water as a CPR is unique because water can be used and reused. For example, one appropriator's use of groundwater for irrigation of a field results in some water percolating into the soil and returning to the aquifer from which it can be pumped and used again by another appropriator. Nonetheless, water resources can be reduced in both quantity and quality.

Extraction of water from aquifers faster than they can be recharged, losses due to evapo-transpiration, and pollution/contamination are some examples of the CPR challenges associated with water management. It is important to identify water as a CPR because this acknowledges that water management is inherently complex and challenging and, therefore, requires special attention for the creation of effective governance strategies. As a CPR, though, it is important to not lose sight of the cultural and environmental significance of water, which is are difficult to address by economic metrics focused on use. Water is often an integral part of spiritual and cultural life of indigenous peoples, and it is an integral part of nature apart from economic services determined by anthropocentric methods of valuation.

Ostrom also utilized a socio-ecological systems understanding of interactions between humans and the environment, which acknowledges that natural resources are influenced by and linked to human social systems that use and manage this natural capital. This social complexity in which ecosystems are interrelated with the economic, legal, political, and cultural realities of a given location creates a dynamic, response driven relationship in which the environment and humans interact with each other. This means that social changes will affect the environment, and environmental change will affect society (Ostrom 2010; Poteete, Janssen, and Ostrom, 2010). Utilization of a socio-ecological systems framework within this research is important because it situates water management strategies within the changing realities of the basin and how human and natural systems modify each other.

Another systems framework that can be applied to managing CPRs, Evans's concept of the "ecology of agents" describes the synergistic effects of a variety of diverse actors complementing and reinforcing one another to bring about some shared goal (such as greater livability). Rather than having the actors such as NGOs, non profit organizations (NPOs), local

public agencies, other groups, and individuals operate in isolation, Evans promotes the maximizing of political potential through their collaboration as a functioning system: an ecology. Evans uses the concept of the ecology of agents to account for organic, positive change that has improved the living conditions of individuals and groups in major cities throughout the world. These diverse yet complimentary agents can exploit synergies among state-society actions to move cities towards greater livability and sustainability (2002, p. 22). This is important considering the presence of a variety of NPOs operating in Ambos Nogales. Connecting these entities to each other and with activists and public agencies on both sides of the border can fill much-needed gaps in the communication and promotion of shared priorities.

The theoretical framework described above is the best suited for the analysis of the research questions, which focus on binational water management approaches, their successes and failures, and the flexibility of the water system to address water scarcity. This framework is ideal because it encompasses and embraces the complexities presented not only by water management in general but also water management across international boundaries in regions of water scarcity. Polycentric governance approaches to CPRs, such as water, situate and address the unique, local needs in Ambos Nogales, a socio-ecological systems understanding frames the interplay between humans and the environment, and the concept of an ecology of agents helps provide strategies for meaningful change in the basin.

METHODS

Ambos Nogales in the Santa Cruz River Basin was chosen as the research focus because it serves as an interesting historical and contemporary example of binational water management that illustrates a variety of complex situations and the successes and failures of the corresponding

strategies. Although every transboundary watershed is unique, Ingram, Laney, and Gillilan (1995) identified that water issues in Ambos Nogales are generally representative of U.S./Mexico borderlands. Therefore, the solutions (both theorized and realized) from this basin can be applied to other prominent border communities such as San Diego/Tijuana and El Paso/Juarez. Also, its relative small size (approximately 240,000 people) in comparison to these other communities made studying this locale more manageable and allowed for greater depth of research.

Original data was collected over a period of twelve months beginning in February 2014 and included on-site research in Phoenix, Tucson, Tubac, Rio Rico, and Nogales, Arizona as well as Nogales and Hermosillo, Sonora. Research methods included analysis of legal and institutional documents, participant observation, informal interviews, and formal interviews. Subsequent reflections of the researcher were recorded in memos. Legal and institutional documents included international treaties, Mexican and U.S. federal and state laws/policies, and memos/transcripts from government sponsored community meetings, all of which were available in online archives. These were used to determine the governance context of the region including the role of public participation. Research also encompassed participant observation of these meetings (N=6), including the International Boundary and Water Commission's Southeast Arizona Citizens' Forum and the Arizona Department of Water Resources (ADWR) stakeholder engagement meetings. This participant observation further explored the public's presence in water management processes.

Informal interviews of managers, officials, hydrologists, academics, and private citizens (N=26) followed a snowball approach in which current respondents helped recruit new individuals. These informal interviews were initially recorded by hand in a notebook with

subsequent, more detailed information being added within a twenty-four hour period. These informal interviews were used to provide various perspectives of the water issues facing the Santa Cruz Basin and to gain insight into cross border relationships. Semi-structured, formal interviews (N=12) targeted key players in water management such as water professionals/managers, government officials, and leaders of nonprofit and non-governmental organizations (NPOs and NGOs). The interviewees were chosen based upon their knowledge of and interest in local water issues and water management. These individuals were intentionally selected to represent an array of experiences and perspectives. All of the formal interviews (each approximately one hour in length) were tape recorded and transcribed for subsequent qualitative analysis. Those interviews conducted in Spanish were translated and back translated to ensure accuracy. These formal interviews sought to provide the technical dimensions of engineering and policy within this binational river basin.

RESULTS AND DISCUSSION

PUBLIC PARTICIPATION

There has been and is currently a general lack of public participation and stakeholder engagement within the decision-making processes in the Santa Cruz River Basin, and definitions of who a stakeholder is can contribute to limiting this participation. Although there is no panacea, political and social activism can serve as one part of potential solutions for addressing this concern. According to Ostrom (1990), the successful managing of CPRs is strongly influenced by engagement and communication between the users of the resource. Voicing the need for and showing public support for greater endorsement of transboundary management, as

well as encouraging robust community involvement in the management process, are extremely compelling instruments of change.

In general, the term stakeholder can be applied to anyone who had a vested interest in a particular matter. However, this definition could be used very narrowly or very broadly. The narrow interpretation restricts stakeholder participation to only those who have specific legal rights (in this case such as riparian property owners), which often limits stakeholder engagement to high profile individuals and groups such as lobbyists, developers, and their lawyers.[24] A more broad interpretation of stakeholder would apply, however, to anyone who was affected by the issue at hand. As applied to water management in the Santa Cruz River Basin, this broad interpretation would associate anyone who relies upon the water from this basin or appreciates the riparian habitat supported by the water (on either side of the border) as a stakeholder. Lack of a clear definition creates tensions, as Dave White of Decision Center for a Desert City (a participatory water management organization) pointed out:

> "[One of] the biggest challenges that we have right now… is the use of the terms not only stakeholders but rights holders. There is a difference… So there are a variety of rights holders and stakeholders that we have within a particular democratic governance system, and there are a variety of these that have both a legal and ethical say in decision-making… Even if one is very conscious about engaging these different communities… it is very difficult to do that across this broad range of players." [25]

[24] ADWR Enhanced Aquifer Management Stakeholder Group. Participant observation. February 2nd, 2014, Phoenix, AZ.
[25] White, Dave, Co-Director of DCDC. Interview with Author. September 26th, 2014, Tempe, AZ.

The discrepancies between interpretations of this term have excluded the public and have insulated the decision makers from the values and needs of the community. Although, by and large the public of Ambos Nogales has not been engaged in city and state water management and development, there have been significant partnerships formed between universities, NPOs/NGOs, utilities, state, and federal levels from both sides of the border, indicating a willingness and desire to be included in water governance matters.

In Arizona there are opportunities for public engagement such as the ADWR's Enhanced Aquifer Management Stakeholder Group, Groundwater Users Advisory Council meetings, and Groundwater, Climate, and Stakeholder Engagement meetings (led by University of Arizona) and the IBWC's Southeast Arizona Citizens' Forum. These are official venues that are open to the public and allow individuals to voice their opinions and concerns. One might question the efficacy of such events and the actual effects of public comments. A current board member of the IBWC's Southeast Arizona Citizens' Forum stated that every public comment made at every meeting is transcribed and sent directly to Edward Drusina, the commissioner of the IBWC. This board member and other IBWC officials explained that this current commissioner is passionate about public engagement and has made the revitalization of the agency's connection with the community a priority.[26] Despite these growing opportunities, there is not significant public attendance nor a representative sample of the public present at these meetings. Water managers, government representatives, envoys of government representatives, conservation groups, and a few concerned citizens make up the majority of the participants. There is often overlap of individuals from meeting to meeting. Some, who are involved in connecting decision

[26] Anonymous, IBWC Southeast Arizona Citizens' board member. Interview with Author. October 2nd, 2014, Rio Rico, AZ.

makers with the public, suggest that the public engages itself only when there is a crisis.[27] It is important to note that the public often does not have the luxury to attend these meetings, as full-time jobs and family obligations that take precedence. The presence of the public at these meetings is not for attendance sake, but is important to have interface between decision makers and those whom the decisions affect. This engagement, as part of a more localized governance strategy proposed by Ostrom's CPR theory, is important for determining the community's needs and for developing specific plans that have the understanding and support of the people.

South of the border, there is a lack of public participation due to an overall absence of formal public meetings. When asked about their opportunities for public participation, a representative of OOMAPAS stated that they have a mailbox for comments and complaints.[28] A representative and engineer from the Comisión Estatal del Agua (CEA) stated that he was not aware of institutional public spaces for participation within water management decisions.[29] Also, CILA does not hold regular citizen forums like their U.S. counterpart (IBWC) does. Mexico was forced to hold public meetings regarding binational border development plans as pursuant to initiatives adopted by the Border Environmental Cooperation Commission (BECC), although Lemos and Luna (1999) have asserted that this participation was extremely limited and had little impact upon policy construction. A former ADWR border liaison who attended these public meetings in Sonora described these as scenes of tension, with "truckloads of army soldiers" in case the crowds and peaceful protesters were to erupt into riots. This same individual alluded to the lack of formal public engagement possibly residing within Mexican culture, with "a cultural

[27] White, Dave, Director of DCDC. Interview with author. September 26th, 2014, Tempe, AZ.
[28] Anonymous, OOMAPAS representative. Interview with author. December 2nd, 2014, Nogales, SO.
[29] Anonymous, CEA representative and engineer. Interview with colleague Adal Durazo. February 6th, 2015, Hermosillo, SO.

respect for hierarchy" within institutions, which hold a disdain for the incorporation of the public.[30]

In an effort to decentralize their control and be more responsive to local situations, Mexico's Comisión Nacional del Agua (CONAGUA) has developed and begun implementing a number of river basin councils known as "Consejos de Cuenca." The role of these councils is to coordinate and execute federal, state, and municipal level water management strategies (CEC, 2001). These councils also include representatives of various stakeholders such as industry, mining, and agriculture. The head of the River Basin Council federal unit of CONAGUA stated that the councils help "promote social participation and facilitate dialogue… between the various organizations involved in the region's water planning." Similar in ways to the United States, this same individual does admit that there is neither complete nor widespread representation (especially of the public) on the councils; s/he cites lack of resources and funding for these shortcomings.[31]

Public engagement is an important aspect for CPR management as it provides local perspectives and insights on local issues to generate local solutions. However, it does bring the possibility of policy and management being led and shaped by a public whose interests run contrary to greater livability and sustainability. An engaged public motivated only by short-term self-interest can derail advances in water management. As a result, it is important to have a floor set by the state from which management decisions cannot fall below a stated minimum.

[30] Anonymous, former ADWR border liaison. Interview with Author. October 22nd, 2014, Tucson, AZ.
[31] Anonymous, CONAGUA official. Interview with colleague Adal Durazo. February 13th, 2015, Hermosillo, SO.

Participatory decision-making is a part of a polycentric governance approach that builds local capacity for the managing of resources. As Ingram, Whiteley, and Perry (2008) stated, "[The] adequate understanding of transboundary water conflicts require[s] a recognition of the multiple and incommensurable meanings of water in all its specific geographical and historical sites of encounter" (p. 15). Key to the recognition of a variety of valuations of the resource is the inclusion and integration of the public within the decision-making processes. This can also be a powerful tool for water equity as in which all those affected by decisions have an opportunity to participate in their creation (Ingram, Whiteley, and Perry, 2008). Considering the relationship between humans and the environment as represented by socio-ecological systems approach, public participation can be an important tool for determining how the public understands their relationship to the ecosystems around them and the value placed on them, from which management plans can be created incorporating these values. Also, the spaces for participatory engagement within the decision-making process can also serve as spaces to connect groups and individuals around common themes and can contribute to the creation of an ecology of agents.

SYSTEM FLEXIBILITY

In their present state, the water management systems in the Santa Cruz River Basin are not flexible enough to address issues of water scarcity. The result has been negative impacts to both livability and sustainability. Nogales, Sonora's continued population growth presents a variety of challenges for future water management. Currently, the management strategies in Sonora are weighted heavily on supply side approaches as opposed to demand, which dramatically reduces the system flexibility in the region. A supply side approach focuses on obtaining greater quantities of water, whereas a demand side approach focuses on reducing the

amount of water used. Considering that the population is not predicted to stabilize until 2060, foresight in water management is key and must incorporate the potential for more unpredictable, extreme weather events that climate change will bring to the region (Scott *et al*., 2012).

In Nogales, Sonora, urban population growth has overwhelmed the municipal infrastructure, and as a result, the human right to water and sanitation is threatened in this region. Approximately 15% of the households in Nogales, Sonora lack piped access to potable water and sewage, which is a barrier to human health and dignity (Norman *et al*., 2012; Scott and Buechler, 2013). Piped sewage systems would not only improve the quality of life of those in *colonia* communities, but would also dramatically improve surface water quality of the entire area, which is plagued by chronic fecal contamination from runoff.

Unlike the U.S. Constitution, the Mexican constitution gives absolute priority to "human consumption" of water (Scott *et al*., 2012). Access to water is not only a universal human right, but in Mexico it is also a domestic legal right indicating that legal avenues could be pursued to help ensure this right. This formal recognition in Mexico is an important step in the fulfillment of human rights and, if utilized, can serve as a powerful tool for vulnerable populations. The poor and most vulnerable in the city have the most to gain from piped water, as based on current rates it would dramatically reduce the percentage of their household budget devoted to water. Recall that bottled water and *pipa* delivered water is much more expensive then municipal sources. There are, no doubt, many difficulties associated with extending coverage in Nogales, Sonora. One of the most imminent is the fact that many *colonia* communities are constructed on rock formations in hilly locations, making piped connections difficult.[32]

[32] Anonymous, CEA official. Interview with colleague Adal Durazo. February 6th, 2015, Hermosillo, SO.

Water transfers from the Los Alisos Basin, as previously described, have extended water scarcity issues to other communities, specifically those in and around Cibuta, Sonora. It is important to recognize where this groundwater goes after it leaves the basin. Currently, 1/3 of the effluent flows in the Santa Cruz River in Arizona are from interbasin transfers from the Magdalena watershed in Sonora. This "extra" water is currently supporting this region of Arizona to the detriment of the Los Alisos basin, where groundwater mining has decreased water tables and where the Los Alisos River has disappeared. In this regard, the concepts of justice and equity should be incorporated into discussions regarding effluent flows north across the border if greater sustainability and livability are to be achieved south of the border. Habitat and livelihoods in the Los Alisos Basin are being threatened by water exported to Arizona in the form of wastewater. A socio-ecological systems approach is needed to encourage holistic thinking that acknowledges these linkages between human consumption and the environment. If equitable situations are desired, then the benefits and burdens of the Santa Cruz River Basin need to be shared between Sonora and Arizona, and communities outside this basin must not be negatively impacted by water management strategies. Currently, much of the discussion regarding the wastewater flows follows a discourse rooted in water for Sonora vs. water for Arizona. These competitive dynamics discount the importance of and need for water throughout the basin system on both sides of the border, and thereby erode underlying motivations for cooperation for CPR management.

In Arizona, the current water budget is dependent upon continued flows of wastewater from Mexico, which support riparian habitat and recharge of the aquifers north of the border. However, these flows can stop at any time if Mexico chooses to do so. Employees of the

NIWTP believe that significant reductions in wastewater below 9.9 MGD will not occur for at least the next fifteen years. Due to continued population growth in this region and the subsidized treatment rates, Mexico is expected to utilize sewage treatment at the NIWTP for the foreseeable future.[33] Mexico, however, hopes to retain its wastewater as quickly as possible with the end goal of keeping 100% and sending none to the United States.

In this regard, conservationists and water users in Arizona see the creation and operation of the LAWTP as a direct threat to water flows in their state.[34] [35] Any future reduction of Mexican wastewater flow to the NIWTP is expected to pose difficulties for riparian habitat and groundwater recharge north of Rio Rico, Arizona. To many residents north of the border, particularly those that value and enjoy the riparian habitat along the Santa Cruz River, the reduction of these flows from Sonora are a serious concern.

The LAWTP has an official capacity of 4.4 MGD, which could signify up to a 4.4 MGD decrease in effluent flows in the Santa Cruz River, contributing to an impact on aquifer infiltration and riparian habitat north of the border (Scott *et al*., 2008). The plant went online in January 2013 and did begin reducing flows to the NIWTP, as it was designed to. During this period, however, sewage flows from Nogales, Sonora were still over the treaty limit (9.9 MGD) 86.8% of the time because of increasing water use. The effluent flow into the Santa Cruz River was reduced, though, from an average of 14.7 MGD (October 2008 to December 2012) to 13.12

[33] Anonymous, U.S. IBWC official. Interview with author. October 2nd, 2014, Rio Rico, AZ.
[34] Santa Cruz River Research Days. Participant Observation. March 27th-28th, 2014, Tucson, AZ.
[35] Anonymous, Santa Cruz River conservationist. Interview with Author. March 28th, 2014, Tucson, AZ

MGD (January 2013 to April 2014). The reduction in effluent flows was not solely caused by the LAWTP, however, but also by decreasing groundwater tables.[36]

Similar to the NIWTP, the effluent from the LAWTP flows south into the Los Alisos River, filtering into the aquifer and helping to address the groundwater mining that has been taking place in this basin for over a decade (Prichard and Scott, 2013). The depletion of the aquifers can create human rights violations when it restricts human access to water from wells and hydrologically connected surface waters. The historical marginalization of this basin is finally being addressed through this (partial) recharge. Facing shortages in their own basin, Nogales, Sonora has acquired water needed to serve its growing population, which has in turn created shortages in the Los Alisos Basin. The LAWTP helps to address the human rights in conflict between Sonoran residents of the Los Alisos Basin and Sonoran residents of the Santa Cruz Basin, both of whom claim the right to potable water. Speaking to the creation of the LAWTP, a prominent member of an Arizonan conservation NPO, lamented the fact that the Arizonan riparian ecosystems are receiving less water now but acknowledged that the return flows to Sonora are important:

> "Yeah, it's definitely a worry. But I don't blame them one bit… We have been getting extra water from another basin, an interbasin transfer for years. So you know, who are we to demand anything. …[It] makes all the sense in the world for them to take some of the sewage back and [to bring] it back to Los Alisos to recharge that basin…" [37]

[36] Anonymous, U.S. IBWC employee. Interview with author. October 2nd, 2014, Rio Rico, AZ.
[37] Anonymous, Arizonan conservationist. Interview with author. March 29th, 2014, Tubac, AZ.

OOMAPAS noted that there are current plans to expand the LAWTP capacity by about 130% and that there are plans to develop additional satellite treatment plants throughout the city.[38] As water scarcity increases in Sonora, the incentives for recharge and reuse from additional treatment plants will grow accordingly.

Commenting on the tension between human use and environmental use, one river conservationist stated, "Yeah, people need water first… [but] laying it out as water for Mexico *OR* water for the river- that's not the right thing, that's not how it should be framed."[39] People need to work to find solutions that benefit both human and environmental requirements if long-term sustainability efforts are desired. Localized wastewater treatment and release of the effluent to support riparian habitat and aquifer recharge is one approach to address both needs. This has been occurring in Arizona for decades, but the upstream aquifers and ecosystems south of the border have not received any of this benefit. It wasn't until the operation of the LAWTP in 2013, that the Nogales, Sonora area began to reclaim some of its own water.

There is widespread agreement from governmental officials and water managers on both sides of the border that LAWTP is a step in the right direction for Ambos Nogales. A U.S. official who was involved in the planning of the LAWTP stated that over a decade ago, in 1994, Mexico negotiated for future aid from the United States for the creation of this plant. He said that "no one thought Los Alisos was going to happen" because of the costs associated with pumping up gradient and the challenges associated with facilitating the binational planning of the

[38] Anonymous, OOMAPAS employee. Interview with Author. December 2nd, 2014, Nogales, SO.
[39] Sass, Sherry, current treasurer and former founder of Friends of the Santa Cruz River. Interview with author. March 29th, 2014, Tubac, AZ.

plant.[40] Representatives of OOMAPAS stated that the decision to create the LAWTP made pure economic sense because as specified in IBWC treaty minute 276, Mexico can only ship 9.9 MDG of wastewater to the NIWTP at a subsidized cost. "Once we exceed that amount we are charged at actual cost, and we have exceeded that amount since 1998 making it very expensive for Mexico to pay such treatment." [41] The plant was created specifically to address these wastewater exceedences.[42]

Contrary to the claims laid forth by many conservationists, U.S. IBWC officials stated that the creation of the LAWTP is beneficial to the United States overall because it reduces Nogales, Sonora's wastewater excesses, which put additional pressure on the U.S. operated NIWTP.[43] Furthermore, two U.S. officials who were active in the creation of LAWTP each stated that the creation of this plant also motivated Nogales, Sonora to develop their own wastewater pretreatment program. Pretreatment programs are essential because they help keep out industrial contaminants that disrupt the biological agents and processes within the wastewater treatment plants. Illegal and improper dumping of chemicals from *maquiladora* factories has and continues to be a problem that crosses international lines. The frequency and severity of industrial contaminants in the shared water systems served as a reminder of the transboundary nature of the management in the Santa Cruz River Basin. The creation of the LAWTP is significant in this context because Nogales, Sonora now has a vested interest in the long-term functioning of their own wastewater treatment plant, and therefore a desire to keep industrial

[40] Anonymous, EPA water and wastewater specialist. Phone interview with author. October 29th, 2014.
[41] Anonymous, OOMAPAS representative. Interview with Author. December 2nd, 2014, Nogales, SO.
[42] Anonymous, CONAGUA engineer. Interview with colleague Adal Durazo. February 13th, 2015, Hermosillo, SO.
[43] Anonymous, U.S. IBWC official. Interview with author. October 2nd, 2014, Rio Rico, AZ.

contaminants out of the sewage flow. This resulted in the creation of a pretreatment program in Sonora, which launched binational efforts to crack down on the illegal dumping of industrial chemicals. In accordance with CPR theory, these efforts involved direct engagement across the border and have been regarded as successful.[44] [45]

If per capita water use continues to grow at current rates, soon both the NIWTP and the LAWTP will be operating over their capacity. This scenario would necessitate not only the construction of more well fields but also the construction of more treatment plants (Prichard and Scott, 2013). Additional infrastructure, although beneficial in addressing short-term water scarcity, does not address the root of the problem. As it stands, current water use and distribution are unsustainable.

Current efforts to plan and build satellite treatment plants are a huge step forward for Nogales, Sonora as the expanding of sewage treatment capacity lays the foundation for more widespread sewage access. These plans also allow Mexico to retain greater and greater volumes of its wastewater, a desire that has long been expressed by Sonorans. Ultimately, the desire is to retain 100% of the water used in Nogales, Sonora, as one CONAGUA engineer stated, the continued trend will be "recovering wastewater, treating it here in Mexico, and utilizing it here in Mexico." [46]

Although Sonora's construction and use of the LAWTP has been widely received as success, their existing water infrastructure presents serious issues. The lack of state capacity is

[44] Anonymous, NPO watershed manager/researcher. Interview with author. October 22nd, 2014, Tucson, AZ.
[45] Anonymous, EPA water and wastewater specialist. Phone interview with author. October 29th, 2014.
[46] Anonymous, CONAGUA engineer. Interview with colleague Adal Durazo. February 13th, 2015, Hermosillo, SO.

one of the greatest challenges to good governance. This research has confirmed historic and continuing infrastructure problems relating to water services in Nogales, Sonora. A former Nogales, Sonora water utility manager who worked for the city in 1986 defined his experience in overseeing water and wastewater services as "chaos". He described an utter lack of organization within the department, stating that none of the underground infrastructure was documented and that only one "older man" knew the locations of the water and sewage pipes.[47] A U.S. EPA official who worked with binational infrastructure developments in Ambos Nogales confirmed that this lack of planning and institutional memory is still a contemporary phenomenon.

> "…[The utility] had no idea where anything was. Anytime they dug a trench they were just tearing up water and wastewater pipes, one after the other…They just start digging a trench, and they find them with a backhoe, which is *not* a great way to go about it. So [it was] a very, very messy situation." [48]

A general lack of utility funding in Nogales, Sonora can be identified as a partial reason for the lack of organization.[49] Without proper funding, adequate manpower and proper training is simply not feasible. Representatives of OOMAPAS stated that largest barrier to their utility's operations is "…the availability of financial resources." [50] But the problem is more than simply funding, as one Sonoran academic stated, "[There is] no planning in water utilities" because

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[47] Anonymous, former Nogales, SO water utility manager. Interview with author. July 29th, 2014, Hermosillo, SO.
[48] Anonymous, EPA water and wastewater specialist. Phone interview with author. October 29th, 2014.
[49] Anonymous, former SCAMA director. Interview with Author. October 27th, 2014, Tucson, AZ.
[50] Anonymous, OOMAPAS representative. Interview with Author. December 2nd, 2014, Nogales, SO.

'local governments are switched every three years, leaving people unable to plan past their term in office because of strong differences in politics and policies.' [51]

More specific cases of these issues of management demonstrated a top-down tendency to focus on water only when these efforts could be used as political capital. One former resident of Sonora who was active with environmental NGOs, indicated that there is a certain "sexiness" about seeking new supplies of water that draws the government to focus on supply-side management.[52] This perpetuates a "culture" that lacks proper operations and maintenance as one former U.S. border infrastructure official stated,

> "Presidents and politicians …will show up every time a reservoir is dedicated, every time a treatment plant is dedicated…[It] carries a lot of political weight to attend those big, visible projects. [But] no president of Mexico…has ever gone to a leak detection project." [53]

The federal government, specifically CONAGUA, has a history of providing grants for new water supplies, such as funding reservoirs and pipelines, while rarely providing grants for the operation and maintenance associated with keeping water systems functioning properly.[54] [55] Without funding to detect leaks and gradually replace old infrastructure, cities are forced to wait to fix problems until there are major system failures. The lack of funding for further

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[51] Anonymous, professor specializing in political science and water management. Interview with author. July 28th, 2014, Hermosillo, SO.
[52] Anonymous, NPO watershed manager/researcher. Interview with author. October 22nd, 2014, Tucson, AZ.
[53] Anonymous, former ADWR border liaison. Interview with author. October 27th, 2014, Tucson, AZ.
[54] Anonymous, CEA official. Interview with author. July 28th, 2014, Hermosillo, SO.
[55] Anonymous, CONAGUA engineer. Interview with author. July 30th, 2014, Hermosillo, SO.

demonstrates the need for more local control of water management through polycentric governance models.

Therefore, utilities such as the one in Nogales, Sonora are stuck in realities of physical, in-basin water scarcity perpetuated by leaks, which have been estimated to be as high as 50-80%. A CEA researcher confirmed this stating, "…the problem in Nogales is not a lack of water volume, the problem in Nogales is the distribution [network]…" [56] Similarly, U.S. officials commenting on the situation south of the border propose that Nogales, Sonora "fix its drinking water system…because if they are losing 50% of what they pump then they can reduce their pumping by 50% just by fixing things." [57] But these same officials do acknowledge that they have no idea where this funding would actually come from.

All past and current water managers interviewed from both sides of the border stressed the need for greater metering of water uses in Nogales, Sonora. Net metering would measure the amount of municipal water used at each end point (each household, industry, store, etc.) and report this information, digitally or through manual inspection, to the utility. One former ADEQ border liaison remarked:

> "They have to measure all their flows at the sources [and] they have to have micro metering in order to measure the deliveries and the difference, …[which] is lost and unaccounted for water… If you can't measure your deliveries you can never

[56] Anonymous, CEA official. Interview with colleague Adal Durazo. February 6th, 2015, Hermosillo, SO.
[57] Anonymous, EPA water and wastewater specialist. Phone interview with author. October 29th, 2014.

know your lost or unaccounted for water. They [the utility] want micro metering, but it seems like there's always one barrier or another, and money is a big one." [58]

By metering virtually all connections in Nogales, Arizona, the local utility has been able to reduce leaks to fewer than 10%. By increasing the net metering of water uses, managers in Hermosillo, Sonora have determined that their city is facing water losses of about 40%, which is both inefficient and inequitable.[59] Also, in 2010, the metering of domestic potable water in some portions of Nogales, Sonora resulted in "dramatic reductions in consumption" (Prichard and Scott, 2013). This was primarily due to the use of price controls to regulate demand.

Officials from OOMAPAS, however, disagreed that price controls would affect demand stating that their city's current household consumption generally covers only basic, inelastic uses, which would not vary significantly with price. Dramatic price increases for domestic potable use would also have devastating consequences on the poor. Since metering of water uses is not a widespread reality in Nogales, Sonora, there are no accurate data representing water use in the industrial sector, although it can be assumed that these volumes are significant. Metering and price controls for industrial water use are not currently happening due in part to the great influence that industry and these foreign owned corporations have on the government. In Mexico, the desire for economic and industrial growth has allowed these corporations to have great latitude with their operations (Cass, 1996).

According to representatives of OOMAPAS, Nogales, Sonora currently has 17.74% of the city's potable water connections metered with an ultimate goal of 100% coverage. Barriers

[58] Anonymous, former ADWR border liaison. Interview with Author. October 22nd, 2014, Tucson, AZ.
[59] Anonymous, Hermosillo water managers. Interview with author. July 28th, 2014, Hermosillo, AZ.

to their metering projects include the high cost of meter installation combined with a chronic lack of funding and problems associated with outdated, poor infrastructure in many parts of the city. As figure 10 shows, previously installed water pipes were placed in close proximity to one another, leaving little if any room for the installation of meters.[60]

Figure 10: Photo of a standard underground water service utility box in Nogales, Sonora [61]

Net metering water use can be seen as part of a greater neoliberal framework that uses the market to try to achieve optimal efficiency in the distribution of resources. Neoliberalism is a political and economic theory and practice that promotes individual entrepreneurial freedoms through "institutional frameworks characterized by strong private property rights, free markets, and free trade" (Harvey, 2005, p. 2). This framework has been widely applied to replace state-led governance with market-friendly policies and approaches. This has led to decentralization and privatization, as seen with the dismantling of state run water entities and their replacement with

[60] Anonymous, OOMAPAS representative. Interview with author. January 7th, 2014, Nogales, SO.
[61] Anonymous, OOMAPAS representative. Interview with author. January 7th, 2014, Nogales, SO.

private utility companies. This is a process that has been occurring in Mexico, and OOMAPAS was the result of such structural reforms and is a private company (Walsh, 2011; Wilder, 2008).

Demand management strategies use the market and price to influence water use of consumers, and net metering allows utilities to charge the user for specific amounts of water as opposed to the monthly block pricing that is commonplace in most portions of Nogales, Sonora. This approach no doubt can have an impact on increasing water conservation by decreasing demand. As a result, these methods are often seen as and used as solutions to state capacity issues. However, these efficiency frameworks of water distribution through market transaction are based within an economic rationality that does not naturally incorporate equity and human rights (Ingram, Whiteley, and Perry, 2008). So these strategies can make it harder for the state to meet human rights obligations, as the price of water can restrict access to this critical resource. It is very important that price never infringe upon the human right to water. Therefore, if the state is to fulfill its obligation regarding the human right to water, demand management approaches employing price (such as increasing block pricing of water) must also include a minimum allotment of water must be subsidized by the state so that everyone has access. The United Nations has defined this amount as no less than twenty liters (5.3 gallons) per person per day (UN, 2010).

CROSS-BORDER COLLABORATION

Providing for the needs of growing urban populations with limited resources is challenging, especially when international boundaries partition jurisdictions. The majority of water managers and officials interviewed who were not employees of the IBWC indicated that the IBWC was a barrier to progress for binational water management. One EPA employee who

focused on binational infrastructure between Mexico and the United States, stated that in his opinion "The IBWC is the least functional agency in the United States government." In an effort to make his direct work with Sonora a success, he excluded IBWC from the negations and "ignored them" as much as possible. CILA's management practices fared no better, and according to this same individual CILA was "intentionally obstructionist in many cases… they didn't want to openly admit that there were problems." [62] IBWC and CILA protocols have been barriers to cross border communication between government water managers and scientists because they prevent them from interacting directly. The official IBWC/CILA protocols stipulate that communication between the nations regarding boundaries and transboundary water be channeled through their organizations. These communication protocols were confirmed by representatives of ADEQ and CEA.

The IBWC is a barrier to communication between the nations and is an example of the failures of the current binational management approach. As official liaisons between the governments of U.S. and Mexico (at local, state, and federal levels), IBWC/CILA can improve relations by offering venues, translators, and structured meeting. However, these protocols inhibit the more direct, casual, and continuous communication needed for ongoing water management in the borderlands [63] (Ingram and White, 1993). This indirect communication facilitated by IBWC/CILA is not only time intensive, but messages and priorities can get distorted and lost in the process. Furthermore, any resulting changes have to be approved as international treaty minutes before any actions could be implemented further delaying any

[62] Anonymous, EPA water and wastewater specialist. Phone interview with author. October 29th, 2014.
[63] Anonymous, U.S. IBWC official. Interview with author. October 2nd, 2014, Rio Rico, AZ.

progress. This works against CPR theory polycentric governance models, as it does not permit local actors to participate directly in binational management.

Politics and policies along the border have often limited and prevented communication between water managers in Arizona and Sonora. In 2008, without consulting water managers on either side of the international line, the U.S. border patrol erected a 5 ft. block wall in an underground culvert connected to Nogales Wash. This was an attempt to stop unsanctioned crossings into the United States, however it also stopped the flow of water north. During a late summer monsoon, held back by the wall, storm water in the wash flooded Nogales, Sonora causing extensive property damage.[64] [65] Six years later, this event was the first topic discussed individually by CEA engineers in Sonora showing that hard feelings still persisted, and that this event and the border patrol in general were inhibiting the formation of trust between managers on both sides.[66]

In 2010, the passing of SB 1070 in Arizona, a strict anti-immigration measure, further eroded binational communication and collaboration efforts and led to a decrease in Mexican support for binational water projects. During this time Mexican engineers and managers demonstrated their disdain for Arizona's law by boycotting meetings in that state. To make matters worse, the U.S. had limited travel of its employees to Mexico during this same time period due to escalating violence in border towns. The U.S. border team had officially stopped working in Mexico, posing barriers to the need for face-to-face communication that Ostrom deemed so necessary for CPR management (Ostrom, Gardner, and Walker, 1994). However,

[64] Anonymous, Arizonan conservationist. Interview with author. March 29th, 2014, Tubac, AZ.
[65] Anonymous, IBWC Southeast Arizona Citizens' board member. Interview with Author. October 2nd, 2014, Rio Rico, AZ.
[66] Anonymous, CEA engineers. Interview with author. July 30th, 2014, Hermosillo, SO.

unofficially some continued to travel to Nogales, Sonora to continue their work with their Sonoran counterparts.[67]

Similarly, Varady, Castelo, and Eden (2012) noted the deterioration of binational coordination in recent history in the form of budget cuts:

> "Over the past decade, the level of federal funding has declined continuously for nearly all aspects of transboundary water management. Especially hard-hit is the already resource-poor citizen-based, stakeholder sector, which holds great potential for improving management practices." (p. 42)

Dramatic increases in funding for border security coincided with dramatic decreases in funding for international cooperation, a policy approach that disregards the intersectionality of security and water management. According to Ostrom (1990), users and managers of the shared water resources need to be able to communicate openly and directly if long-term resource sustainability is to be achieved.

Consistent with Ostrom's theory regarding CPRs, significant, positive change within the binational Santa Cruz River Basin in regards to water management and water access has come through NPO, NGO, and university partnerships with and within the community. This positive interaction and synergy between communities, NGOs, and local public agencies lies in what Peter Evans (2002) called "the ecology of agents" (p. 23). A diverse array of actors all working together in different yet complimentary ways to promote a particular cause is one of the most productive ways to advance social and environmental change. The collaboration of these agents helps connect social movements with state insiders "…who put a priority on livelihood and

[67] Anonymous, EPA water and wastewater specialist. Phone interview with author. October 29th, 2014.

sustainability" and create positive change through "state-society synergy" (p. 239). According to Evans, translocal actors such as NGOs play crucial roles in promoting livability and sustainability because they are able to construct alliances and increase political leverage (p. 18).

One Sonoran native and former member of the NPO Sonoran Institute, led an almost decade long project (from 1999- 2008) to help restore the upper Santa Cruz River in Sonora, which feeds into Ambos Nogales. Working directly with ranchers in the area, they implemented a variety of strategies such as fencing to limit cattle grazing along the riparian corridor and gabions to slow the overland flow of water, among others, which helped improve the quality of river's water, subsequently improving health conditions for downstream users.[68] This project also engaged the community with water quality assessments, and used this citizen science to help provide comprehensive data about the sources of freshwater within the Santa Cruz River Basin. This sampling filled in gaps in government data and was used by various entities including government agencies to help determine sources of water contamination. NPOs have also been active in promoting ecotourism along the Santa Cruz River. In the community of San Lázaro, Sonora, NPOs engaged the community (specifically the youth) to educate them about the riparian wildlife in their area. With the help of these NPOs, the youth established Los Halcones, a bird watching organization, that conducted bird surveys for conservation groups and also led bird watching tours, which brought economic growth to the region through eco tourism.[69] [70]

[68] Anonymous, NPO watershed manager/researcher. Interview with author. October 22nd, 2014, Tucson, AZ.
[69] Sass, Sherry, current treasurer and former founder of the Friends of the Santa Cruz River. Interview with author. March 29th, 2014, Tubac, AZ.
[70] Anonymous, IBWC Southeast Arizona Citizens' board member. Interview with author. October 2nd, 2014, Rio Rico, AZ.

According to one U.S. borderlands water manager, NGOs "…played a big part in [the] environmental side agreements [to binational border development work]…and incorporated provisions for public engagement that would apply on both sides of the government."[71] One regional director of CILA was described as having been very skeptical of NGOs as people trying to take government jobs, but later appreciating the work that they carried out and "listening" to them. Other NPOs also aided the Mexican and U.S. state/federal governments by carrying out water quality assessments throughout the Santa Cruz River Basin when government funding and personnel were not available. This data was key to providing continuous monitoring of flows and of possible illegal contamination from *maquiladoras* and third party waste disposers.[72] [73]

Professors from the University of Arizona have also formed partnerships across the border through funding from the federal government and various NPOs in Arizona. One Sonoran professor and CEA official promoted the successes of these partnerships stating, "…[Through] the relationship we have with other academic groups at the University of Arizona we have made some very concrete actions." [74] Many of these projects have worked with *colonias* to provide dry composting latrines and sanitation education to improve health and quality of life of those residents. These efforts have also led to the creation of environmental organizations within the local schools to help teach primary and secondary education students about sustainability.[75]

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[71] Anonymous, former ADWR border liaison. Interview with author. October 22nd, 2014, Tucson, AZ.
[72] Sass, Sherry, current treasurer and former founder of Friends of the Santa Cruz River. Interview with author. March 29th, 2014, Tubac, AZ.
[73] Anonymous, IBWC Southeast Arizona Citizens' board member. Interview with author. October 2nd, 2014, Rio Rico, AZ.
[74] Anonymous, CEA official. Interview with colleague Adal Durazo. February 6th, 2015, Hermosillo, SO.
[75] Anonymous, IBWC Southeast Arizona Citizens' board member. Interview with author. October 2nd, 2014, Rio Rico, AZ.

Specifically, the University of Arizona is invested in the *Asociación de Reforestación en Ambos Nogales* (ARAN; Ambos Nogales Reforestation Partnership), which is funded by BECC and links together academia, NGO/NPOs, and concerned citizens from Arizona and Sonora to help address issues of human health and environmental sustainability. Founded in 2003, the general goals of ARAN are to foster environmental leadership and to advance sustainability awareness through community-based research and community-based service and social learning (Austin, 2010). According to NGO/NPO organizers on both sides of the border, over the years ARAN has helped link the communities together and has enhanced the quality of life in Nogales, Sonora by providing education on sanitation and hygiene and helping implement the use of composting latrines to reduce fecal contamination. Not only has this been a health benefit for the *colonias* and the greater city of Nogales, Sonora, but also it improves the quality of water flowing north across the border into Arizona.[76] [77]

The Transboundary Aquifer Assessment Program (TAAP) -- a partnership between the University of Arizona and the USGS in collaboration with Mexican counterparts at local, state, and federal levels -- was established in 2007 with the goals of characterizing and modeling the shared aquifers of the San Pedro and the Santa Cruz Rivers, as well as building a shared vision of management strategies (Wilder *et al.,* 2010). Interviews conducted with members of CONAGUA have confirmed the University of Arizona's positive role in engaging the technical and policy aspects of water management and helping facilitate dialogue across the US/Mexico

[76] Anonymous, Arizonan conservationist. Interview with author. March 29th, 2014, Tubac, AZ.
[77] Anonymous, IBWC Southeast Arizona Citizens' board member. Interview with author. October 2nd, 2014, Rio Rico, AZ.

border.[78] According to Wilder *et al*. (2010), TAAP has been and continues to be a successful medium of binational exchange, social learning, and sustained interaction that draws together stakeholders, scientists, and decision-makers from across national lines to confront the present and future challenges associated with water resources.

As emphasized in interviews with key informants, significant positive change in Ambos Nogales has been the result of the dedicated efforts of Arizona water specialists who directly engaged with their counterparts in Nogales, Sonora. The City of Phoenix volunteered to work with Sonoran engineers and provided them with detailed training in wastewater pretreatment technologies to help them develop their own pretreatment program.[79] Also, one ADEQ hydrologist, who specializes in environmental protection along the border, has made it his official and unofficial mission to confront and solve the problems and challenges of this borderlands region. From those within water governance, he was described as a central leader in border initiatives, "somebody who's willing to say I am accountable, [and] I am going to make this happen." [80] From those in the NGO/NPO sector he was called a "godsend" that did his work from the heart.[81] Comfortable with the Spanish language and Mexican culture, he was able to spend significant amounts of time South of the border directly engaging engineers, utility managers, and elected officials focusing most of his energy cracking down on illegal dumping of

[78] Anonymous, CONAGUA engineer. Interview with colleague Adal Durazo. February 13th, 2015, Hermosillo, SO.
[79] Anonymous, former ADWR border liaison. Interview with author. October 22nd, 2014, Tucson, AZ.
[80] Anonymous, EPA water and wastewater specialist. Phone interview with author. October 29th, 2014.
[81] Anonymous, Arizonan conservationist and federal employee. Interview with author. October 2nd, 2014, Rio Rico, AZ.

heavy metals by *maquiladoras*, and helping to establish water quality standards and pretreatment programs initiated earlier.

He went above and beyond his official requirements working off the clock in Sonora with his Mexican counterparts, in ways that were not official sanctioned by either government. As one IBWC official stated:

> "[He] was working with OOMAPAS and the local municipality over there, but we don't look at that. We're not trying to stop him, and we actually unofficially encourage him to get things done, whereas going through our bureaucracy it sometimes can't happen as effectively or efficiently." [82]

Official cross border planning and management of water resources goes through IBWC/CILA as the intermediary for the two countries. Through this process, actions also require authorization before they can be implemented. By circumventing these often long and arduous processes, this individual's efforts were direct, timely, and effective. His unofficial, unpaid work with Sonorans helped supply the momentum, passion, and technical expertise that provided the impetus for Nogales, Sonora's first industrial pretreatment program, which combats the issues of chronic toxic dumping from factories that had contaminated washes and groundwater and disrupted the biological treatment at the NIWTP. He stands as a testament to the power of small-scale, intra-personal relationships in enacting large-scale change and to the strengths of Ostrom's polycentric governance approach to CPRs. Unfortunately, however, in November of 2014 this individual's superiors instructed him to cease all collaboration with those south of the border. The stated rationale for this order was that it was not his official job but that of the IBWC to address the water quality issues. Since November 2014 up through the completion of this paper in April

[82] Anonymous, U.S. IBWC official. Interview with author. October 2nd, 2014, Rio Rico, AZ.

2015, there has been no cross-border collaboration in this sector and spikes in industrial contaminants have become more frequent.

FUTURE CONSIDERATIONS

The Santa Cruz River Basin demonstrates the complex realities of transboundary resource management. A shift in water management strategies to increase pubic participation within decision-making, increase the flexibility of the water systems, and increase cross-border collaboration is needed to ensure human and ecological sustainability in the Santa Cruz River Basin. A historic and present lack of community engagement within the decision-making processes has disconnected policy makers from the context, perspective, and needs of those living in the basin, and therefore decreased the effectiveness of management approaches. Also, in the present state, the systems in place are not flexible enough to deal with future water scarcity. Current groundwater pumping south of the border is unsustainable, and safe yield conditions north of the border are dependent upon continued effluent flow from Sonora. Projected growth in this region and possible climate change scenarios will only complicate these issues. Further eroding the ability to adapt to these situations is the absence of effective cross-border communication and collaboration. Binational river basins necessitate binational management, and without meaningful interactions across the border all will share in consequences of governance failures. By incorporating direct communication and local capacity as per common pool resource theory, recognizing the connections and implications of our management actions through socio-ecological systems understanding, and promoting the organic drivers of change through ecologies of agents, just and vigorous futures can be envisioned and advanced.

In reality, effective change will be piecemeal. Long-term change will result from the accumulation of small steps forward in the right direction. Keeping this in mind, there are priorities to the actions that would lead to greater livability and water sustainability in this basin. The most pressing issues to address are the lack of water and sanitation in the *colonias* of Nogales, Sonora. Not only is this a serious issue for those living in the communities, but also one that affects the entire basin with possible fecal contamination. Connecting these communities to municipal potable water and sewage is a priority, yet is challenging. One potential solution to the feasibility of connecting *colonias* to piped water is the creation of affordable housing communities within the city. These can be small communities integrated throughout Nogales, Sonora in locations where municipal connections already exist. However, this could result in the break up of established communities, necessitating that these integration processes be mindful of the original residents. In the mean time, OOMAPAS has organized programs to provide *colonia* households that do not have access to piped water with *tandeos* (large storage containers) for holding water.[83]

Providing increasing coverage of municipal connections would increase the demand for water and would increase groundwater pumping in aquifers already facing net losses. In the short-term, more well fields in the Los Alisos Basin would need to be constructed and utilized if increased water demand in Nogales, Sonora were to be met. Engineers from CONAGUA and OOMAPAS have confirmed the need for more water from and plans for more wells in this basin.[84] [85] Ideally, though, effluent recharge as identified previously in the LAWTP may help to

[83] Anonymous, OOMAPAS representative. Interview with author. January 7th, 2015, Nogales, SO.
[84] Anonymous, OOMAPAS representative. Interview with author. December 2nd, 2014, Nogales, SO.

balance out these withdrawals and capped or decreased consumption from industry could alleviate the need for interbasin transfers.

To create an even more equitable scenario, the capacity of the LAWTP could be expanded to be equivalent to the pumping from this basin, resulting in zero net losses. As was originally planned, solar energy sources could be fully utilized to incentivize continued shipments of wastewater to this basin by helping to cover or offset the costs of pumping up gradient to the Los Alisos divide. To further aid in this process of groundwater recharge, micro, decentralized wastewater treatment plants could be established near all major well fields in the city, so that the treated effluent can be incorporated back into the environment and back into the municipal water system as indirect reuse. These ideas have been voiced by CEA researchers, who see the injection of treated effluent into the aquifers as future sources of water for the Sonoran communities.[86] Care needs to be taken, however, to ensure the constant quality of this treated effluent, as failure to do so would put public health at risk. This level of water quality would require extensive investment in advanced wastewater treatment technologies. Another, simpler option would be to use treated effluent for non-food crop irrigation and for certain appropriate industrial processes in *maquiladoras*.

Another crucial step is to fix, update, and maintain Nogales, Sonora's water and wastewater infrastructure. By fixing leaks in the system, OOMAPAS could dramatically reduce groundwater pumping and energy expenditures associated with it. Key to identifying these leaks is the widespread use of water meters, which can show where there are discrepancies between

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[85] Anonymous, CONAGUA official. Interview with colleague Adal Durazo. February 13th, 2015, Hermosillo, SO.
[86] Anonymous, CEA researcher. Interview with colleague Adal Durazo. February 6th, 2015, Hermosillo, SO.

water in and water out. This requires significant capital and expertise, though. Increasing taxes on foreign owned mining corporations and *maquiladoras* could provide an adequate funding base for infrastructure improvements. However, given the global context of trade liberalization, these factories would most likely move to cheaper locations as opposed to paying higher taxes. An exodus of *maquiladoras* from the borderlands would dramatically reduce water use and contamination, but it would also leave many unemployed who depended upon the jobs (albeit poor conditions, low-wage, and insecure) provided by this industrial sector.

Being a binational basin, Arizona has a vested interest in Nogales, Sonora's water systems, and could also help provide support to help build and augment state capacity. There are numerous precedents for this type of partnership, some of which were identified previously. These partnerships with Arizona are critical for establishing momentum in water management. The need for greater collaboration and communication across the border can best be addressed by the easing of restrictions imposed by the IBWC to permit local actors to engage across the border. Until this happens, however, this burden of collaboration will be placed on universities, nonprofits, and nongovernmental organizations that have much more latitude in their work than government employees.

As water availability continues to decline, legally sanctioned water transfers enforced by the government in Sonora could extend the supply. This indicates the potential for future agriculture to urban water transfers, as have been common in the state of Arizona. However, agriculture in the Nogales, Sonora area is currently minimal, so these transfers would not be an adequate solution. A more apt version of water transfers could be from industry, such as *maquiladoras* and mining operations, to municipal use. These transfers could be mandated and legally enforced under Mexico's constitution, which gives priority to human consumption of

water. In addition to or possibly in lieu of water transfers, metering industrial connections and implementing increasing rates for these non-human consumption water uses could reduce water demand or at the very least generate revenue, which the utility could use to help implement its other anticipated projects and recoup some of the costs that might otherwise be imparted onto households. One U.S. EPA member stated that he would love to see industrial metering coverage so that the mines would pay for the water they have been "stealing" for years. However, these industries wield tremendous political power especially in a context where corruption is the norm, which would create large barriers to the realizations of rate increases or water transfers[87] (Cass, 1996; Spalding, 2002).

There is a need for an open and consistently offered dialogue space in Sonora for individuals to share their concerns and needs with the government and the utility. Following the models established by IBWC, citizen's forum meetings could be hosted by CILA in Sonora. This would also bring the possibility of hosting binational forums that could put members of the public on either side of the border in dialogue with each other. This exchange of information could help these bodies focus their efforts on issues that are most urgent and pressing for the public. This communication could also enhance trust between parties and public confidence in the utility. Greater education about water issues could help encourage active public participation within water management. It is important that this education is put forth from trusted sources; otherwise the information will be dismissed. Local news media sources such as *Nogales International* newspaper and *Nuevo Día* newspaper could have prominent roles in promoting and disseminating the information to Ambos Nogales.

[87] Anonymous, EPA water and wastewater specialist. Phone interview with author. October 29th, 2014.

It is also important to look to the Arizonan communities for their role in groundwater withdrawals and their capacity to be a part of the solution. Although Nogales, Arizona is not experiencing the rapid population growth of Nogales, Sonora, they use significant amounts of water from the shared aquifer. Their total population is only 10% of Nogales, Sonora, but individuals north of the border use four times as much water per capita as do their neighbors to the south (Frisvold and Osgood, 2011; Scott and Buechler, 2013). The standard of living is much higher north of the border. Homes are larger, landscaping is popular, and private and public swimming pools are present. Houses can be seen with turf grass lawns, extensive gardens, and flush toilets, and there are a total of three golf courses in the upper Basin. As water shortages increase in the binational basin, water use in Arizona will come under greater scrutiny. However, proactive management now can help defer future crises. The implementation of an increasing block pricing for municipal water (while keeping basic water for human consumption subsidized) could provide the economic incentive to conserve, such as the installation of infrastructure to reuse gray water, while the investigation of leaks and illegal water connections can reduce unaccounted for water supplies. Furthermore, implementing the Assured Water Supply rules for the Santa Cruz AMA would promote water conservation efforts and aid in water management. These rules assert that new developments, such as subdivisions, must prove the availability of a one hundred year water supply before development will be approved. Also important are public education efforts to promote the wise use of this dwindling resource. Programs such as the University of Arizona's Conserve to Enhance have promoted collective environmental and personal economic incentives to be mindful of one's water consumption habits, to change behaviors, and to install/retrofit water saving technology. This program has

been successful in Tucson, Arizona and could be easily transferred to other communities such as Nogales, Arizona.[88] [89]

CONCLUSIONS

The troubled past and present, as well as the uncertain future of water use and water management in Ambos Nogales illustrate the importance of this resource especially when communities are confronted with scarcity. Integrated water resource planning and development and increased cooperation among actors are key elements to the water scarcity issues facing this community and the Santa Cruz River Basin. Promoting equity, efficiency, and sustainability through management strategies that incorporate the varying uses of water and the interdependencies between and among resources such as land and water is an essential step to diversifying techniques and stepping out of a one-size-fits-all governance approach. All water basins are different and carry unique social, political, legal, economic, and environmental circumstances that cannot be addressed through broad stroke legislation. This is especially apparent given the striking differences between governance in Nogales, Sonora and Nogales, Arizona. A nested or polycentric governance approach, as advocated by Ostrom (2007), could help create local level solutions to local level problems present in Ambos Nogales. These strategies must include both supply and demand side approaches to water management if water scarcity is to be addressed in both the short and long term. These would include continued well field development in the Magdalena watershed to support the city's growing population, the

[88] Santa Cruz River Research Days. Participant observation. March 28th, 2014, Tucson, AZ.
[89] Sass, Sherry, current treasurer and former founder of Friends of the Santa Cruz River. Interview with author. March 29th, 2014, Tubac, AZ.

repairing of old infrastructure and the fixing of water leaks, and education about the importance of water conservation.

Command and control approaches from overarching governing bodies have been generally ineffectual when it comes to bringing meaningful change to the Santa Cruz River Basin. These large-scale governing bodies, particularly those at the federal level, have been and continue to be very slow to respond to the needs of and consultation and participation with the local communities in Ambos Nogales. Mired in bureaucratic chains of command and official protocols regulating communication and action and generally removed from the communities in question, these organizations are unable to adapt to the changing and growing challenges of water management (Eckstein, 2013). These federal and international agencies represent an institutional mismatch for addressing and resolving the transboundary water issues in the borderlands. Local water should be managed with a local perspective from local leaders following Ostrom's (2010) approach, which nests these decentralized units within greater and greater encompassing units. Each basin is different and therefore needs a unique and tailored management plan, something that federal and international agencies alone struggle to achieve.

A paradigm shift in water governance is also crucial to adapting to uncertain futures. Although, formal treaties and federal organizations do have a role in this management, they should neither be the first nor last word on the subject. Local leaders should be given more autonomy to work across borders at the basin level to develop unique solutions to unique problems. Unlike remote governance, those within the communities have a vested interest in preserving their resources. This local level cooperation and collaboration across international lines promotes the sharing of perspectives and knowledge and the building of relationships,

which are key to developing and implementing sustainable solutions that reflect the complexities of transboundary water resources (Lemos and Morehouse, 2005; Morehouse *et al*., 2008).

Binational water management strategies inherently call for cooperation and communication between and among government officials, water managers, and the public. Crucial to this interaction is the creation of a "dialogue space" for water management that promotes public awareness/education and encourages widespread engagement within the decision-making process (Moss *et al*., 2003). Political and social activism that come from this greater awareness and engagement can serve as a potential vehicle to address the concurrent issues facing the region. Public support for holistic management can be a compelling instrument of change, but key to these dynamics and their success is the momentum provided by an ecology of actors working together on shared concerns (Evans, 2002). Already, positive change has come from significant partnerships formed between the public, NGOs/NPOs, and government entities, and these must continue in Ambos Nogales if long-term water resource sustainability is to be achieved for this border community. The relationships provided by these ecologies of actors create greater leverage in the pursuit of social transformation.

The need to confront, embrace, and address complexity from the ground up is vital to the future of Nogales and the Santa Cruz and Alisos rivers, as the over simplification of the issues facing this region and the imposition of inflexible management policies without the consideration of local stakeholders is a recipe for disaster. Responding to a question regarding the inherent complexity of this situation, a professional translator and community activist remarked, "Yes [it's complex], but it brings with it diversity and creativity, which are powerful tools- you just

have to open your eyes." [90] The water use and management issues facing Ambos Nogales including rapid population growth and urbanization spurred by NAFTA and increasing groundwater withdrawals impacting ecosystems and marginalizing the residents of Los Alisos are very daunting indeed. But, there is no doubt that with open eyes, the diversity and creativity endemic to the borderlands can help forge innovative solutions for an equitable and sustainable future in the Santa Cruz River Basin.

[90] Anonymous, private citizen, activist, and translator. Interview with author. March 28th, 2014, Tucson, AZ.

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